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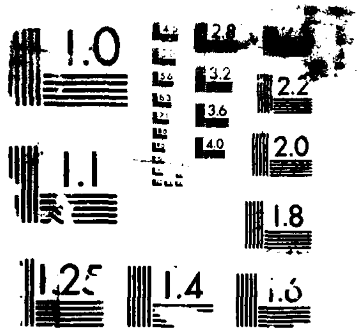
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AD-A189 334

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COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT ITL-87-5

SLIDING STABILITY OF CONCRETE STRUCTURES (CSLIDE)

by

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Waterways Experiment Station, Corps of Engineers
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Final Report

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PROGRAM INFORMATION

Description of Program

CSLIDE, called XØØ75 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) Library, is a computer program for the sliding stability analysis of concrete structures using the limit equilibrium method described in the Engineering Technical Letter (ETL) 1110-2-256. A description of the analysis procedures used in the program and instructions for using the program are provided in the Waterways Experiment Station (WES) Instruction Report ITL-87- __, "Sliding Stability of Concrete Structures (CSLIDE)", dated _____ 1987.

Coding and Data Format

CSLIDE is written in FORTRAN77 and is operational on the following systems:

a. US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., and Division office Honeywell DPS/8.

b. District office Harris 500.

c. Cybernet Computer Service's CDC CYBER 175.

d. IBM compatible PC.

Data are input to the program from a prepared data file in free field format or from the user's terminal during execution. If data are input from a terminal, the user may enter data by using key command words or by following a prompting sequence. Output from the program may be directed to a file or printed at the user's terminal. If graphics are desired, the terminal must be a Tektronix 4014 or, in the case of the microcomputer version, either a Color Graphics (CGA) or an Enhanced Graphics (EGA) display.

How to Use CSLIDE

Directions for accessing the program on each of the three systems is provided below. It is assumed that the user can sign on the appropriate system before attempting to use CSLIDE. In the example initiation of execution commands below, all user responses are underlined, and each should be followed by a carriage return.

Honeywell System

After the user has signed on the system, the system command FORT brings the user to the level to execute the program. Next, the user issues the run command

RUN WESLIB/CORPS/XØØ75,R

to initiate execution of the program. The program is then run as described in this user's guide. A data file is typically prepared prior to issuing the run command. An example initiation of execution is as follows:

```
HIS TIMESHARING ON Ø3/Ø4/81 AT 13.3Ø1 CHANNEL 5647
USER ID - RØKACASECON
PASSWORD - WHERE/ARE/YOU?
*FORT
*RUN WESLIB/CORPS/XØØ75,R
```

CYBERNET System

The log-on procedure is followed by a call to the CORPS procedure file

OLD,CORPS/UN=CECELB

to access the CORPS library. The file name of the program is used in the command

BEGIN,,CORPS,XØØ75

to initiate execution of the program. An example is:

```
84/12/Ø5.  16.41.ØØ.  AC2F5DA
EASTERN CYBERNET CENTER SN9Ø4 NOS    1.4/531.669/2ØAD
FAMILY:  KOE
USER NAME:  CEROXX
PASSWORD -
XXXXXXXX
TERMINAL: 23, NAMIAF
RECOVER/CHARGE:  CHARGE,CEROEGC, CEROXX
$CHARGE
12.49.07.  WARNING (various information messages may appear here)

11/29 FOR IMPORTANT INFO TYPE EXPLAIN, WARNING.  (Various information messages
                                                  may appear here.)

OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,XØØ75
```

Harris 500 System

The log-on procedure is followed by a call to the program executable file, with the user typing the asterisk and file description

*CORPS,XØØ75

to initiate execution of the program. An example is:

```
"ACOE-ABLESVILLE (H500 V3.1)"
ENTER SIGN-ON
1234ABC, STRUCT
```

```
**GOOD MORNING STRUCTURES, IT'S 7 DEC 84 Ø8:33:12
AED HARRIS 500 OPERATING HOURS 0700-1800 M-S
*CORPS,XØØ75
```

IBM Compatible Personal Computer

If CSLIDE is installed under the directory CORPS with the executable file name *XØØ75, then type*

```
/CORPS/XØØ75
```

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the Honeywell system is:

```
RUN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

on the Cybernet system, the commands are:

```
OLD,CORPS/UN=CECELB
BEGIN,,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

on the Harris system, the commands are:

```
*CORPS
ARE YOU USING A PRINTER TERMINAL OR CRT?
ENTER P OR C
P
CORPS SYSTEM COMMANDS:
BRIEF - LIST EXPLANATION OF A PROGRAM.
EXECUTE - RUN A CORPS PROGRAM.
LIST - LIST THE AVAILABLE CORPS PROGRAMS.
STOP - EXIT FROM CORPS SYSTEM MACRO.
HELP - HELP AND EXPLANATION OF CORPS
       SYSTEM AND THE RUNNING OF ITS MACRO.

NOTE:  COMMANDS MAY BE ABBREVIATED TO THE
       FIRST LETTER OF THE COMMAND.

ENTER COMMAND (BRIEF,EXECUTE,LIST,HELP,STOP):
LIST
```

This capability is not yet implemented on the Apollo.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a documentation of the computer program (CSLIDE) which was developed to assess the sliding stability of concrete structures using the limit equilibrium method described in ETL 1110-2-256, "Sliding Stability for Concrete Structures."

CSLIDE can compute the factor of safety against sliding considering the effects of numerous and varied conditions. The report is organized to present an overview of the sliding analysis and the capabilities of the program, to discuss the development of the equations used in the sliding analysis, the analysis procedures and their implementation into the program, to discuss the program input and output, and to present a user's guide.

The appendixes include example problems which demonstrate the capabilities of CSLIDE, hand solutions which verify the program results, routine descriptions, a flow chart of the program, and a description of the symbols used in the report.

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PREFACE

This report documents CSLIDE, a computer program for assessing the sliding stability of concrete structures. Funding for the development of the program and preparation of this report was provided to the Information Technology Laboratory (ITL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., by the Engineering and Construction Directorate of the Office, Chief of Engineers (OCE), US Army, under the Computer-Aided Structural Engineering (CASE) and the Geotechnical Aspects of CASE (G-CASE) Projects.

Specifications for the program were prepared by the members of the CASE Task Group on G-CASE. Members of the task group during the development of the program were as follows:

Mr. Phil Napolitano, Chairman, New Orleans District
Dr. Roger Brown, South Atlantic Division
Mr. Frank Coppinger, North Atlantic Division
Mr. Richard Davidson, OCE
Mr. Ed Demsky, St. Louis District
Mr. Lavane Dempsey, St. Paul District
Mr. Bill Strohm, WES
Mr. Charles Trahan, Lower Mississippi Valley Division
Mr. Tom Wolff, St. Louis District
Mr. Reed Mosher, WES
Ms. Virginia Noddin, WES
Mr. Michael Pace, WES
Dr. N. Radhakrishnan, WES

The main analysis algorithm was written by Dr. Jay K. Jeyapalan, Department of Civil Engineering, University of Wisconsin at Madison, under Contract No. DACW 39-84-M-1903. This work was done under the direction of Mr. Reed Mosher, Engineering Applications Group (EAG), ITL, WES, and Mr. Dennis Williams, Huntsville Division, formerly of ITL. Mr. Williams also provided additions and modifications to the program. Subsequently, Mr. Michael E. Pace and Ms. Virginia R. Noddin, EAG, ITL, WES, made additional enhancements to the program and conducted an extensive testing and debugging effort to complete the development of the program. Graphics for the program were written by Mr. Pace.

This report was written by Mr. Pace and Ms. Noddin under the guidance of Mr. Mosher. The project was under the general supervision of Mr. Paul K. Senter, Chief, Scientific and Engineering Application Division, ITL, WES, and Dr. N. Radhakrishnan, Chief, ITL, and CASE Project Manager. The OCE Technical

Monitors were Messrs. Lucian Guthrie and Donald R. Dressler. This report was prepared for publication by Editor Gilda Miller and Editorial Assistant Deborah Shiers, Information Products Division, ITL, WES.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees	0.01745329	radians
feet	0.3048	metres
kips (1,000 lb force)	4.448222	kilonewtons
kips (mass) per cubic foot	16018.463	kilograms per cubic metre
kips (force) per square foot	47.880263	kilopascals

SLIDING STABILITY OF CONCRETE STRUCTURES (CSLIDE)

PART I: INTRODUCTION

Purpose of Program CSLIDE

1. CSLIDE was developed to assess the sliding stability of concrete structures using the limit equilibrium method described in the Engineering Technical Letter ETL 1110-2-256, "Sliding Stability for Concrete Structures."*

2. CSLIDE can compute the factor of safety against sliding by considering the effects of:

   a. Multiple soil layers with irregular surfaces.

   b. Water and seepage.

   c. Applied vertical surcharge loads which include line, strip, triangular, uniform, and ramp loads.

   d. Applied horizontal point loads.

   e. Irregular shaped structural geometry with a horizontal or sloped base.

   f. A percentage of the base of the structure in compression due to overturning.

   g. Single or multiple failure planes.

   h. Horizontal and vertical induced loads due to earthquake accelerations.

   i. Factors which require the user to predetermine the failure surface.

Organization of Report

3. The remainder of the report is organized as follows:

   a. Part II gives an overview of the sliding stability analysis and defines pertinent terms used in the remainder of the report.

   b. Part III discusses the theory involved in the limit equilibrium method presented in ETL 1110-2-256.* The assumptions used in this method are presented, and the general wedge equation is developed.

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* Headquarters, Department of the Army. 1981 (Jun). "Sliding Stability for Concrete Structures," ETL 1110-2-256, Washington, DC.

c. Part IV discusses the analysis procedure and how it is implemented in the program.

d. Part V provides an overview of the program capabilities.

e. PART VI discusses the program input. The conditions which warrant the use of the options and the data that are required for the options are discussed.

f. Part VII describes the output from the program.

g. Part VIII contains the user's guide for the program.

h. Appendix A solves several example problems to demonstrate the capabilities of the program.

i. Appendix B provides complete hand solutions for two sliding problems to verify the results obtained from the program.

j. Appendix C contains a description of each routine in CSLIDE and a flowchart.

PART II: OVERVIEW OF SLIDING STABILITY ANALYSIS

4. The purpose of a sliding stability analysis is to assess the safety of a structure against a potential failure due to the effects of excessive horizontal deformations. The potential for a sliding failure may be assessed by comparing the applied shearing forces to the resisting shearing forces. The resisting shearing forces are forces which are available due to the shear strength of the geologic material along an assumed failure surface. A sliding failure is imminent when the ratio of the applied shearing forces to the available resisting shearing forces is equal to one along an assumed failure surface.

5. The shape of the failure surface may be irregular depending on the homogeneity of the backfill and foundation material. The failure surface can be composed of any combination of plane and curved surfaces. For simplicity, all failure surfaces in CSLIDE are assumed to be planes which form the bases of wedges as shown in Figure 1.

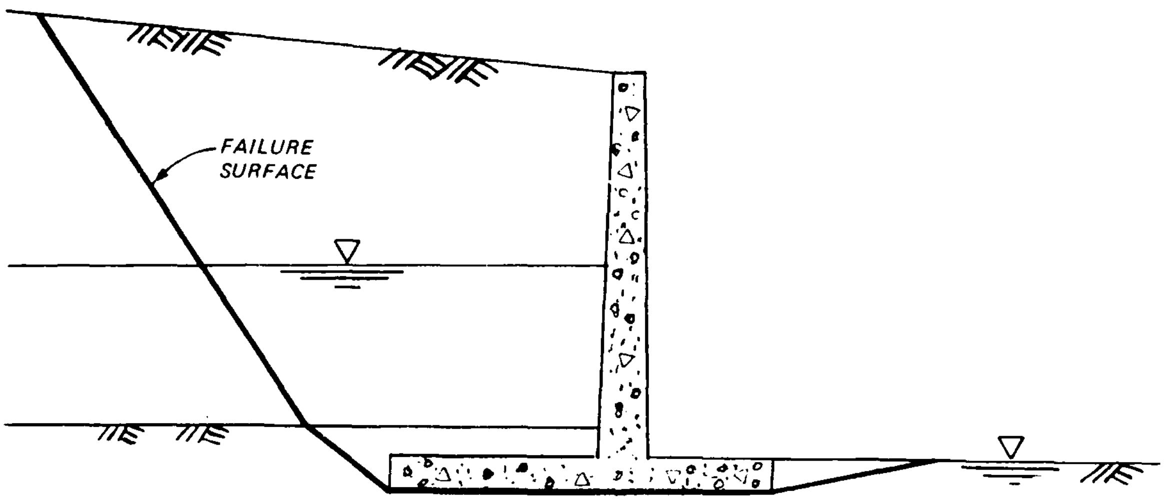


Figure 1. Typical soil/structure system with an assumed failure surface

6. Except for very simple cases, most sliding stability problems encountered in engineering practice are statically indeterminate. To reduce a problem to a statically determinate one, the problem must be simplified by dividing the system into a sufficient number of wedges and arbitrarily assuming the direction of the forces which act between the wedges.

7. Figure 2 illustrates how CSLIDE would divide the previously shown

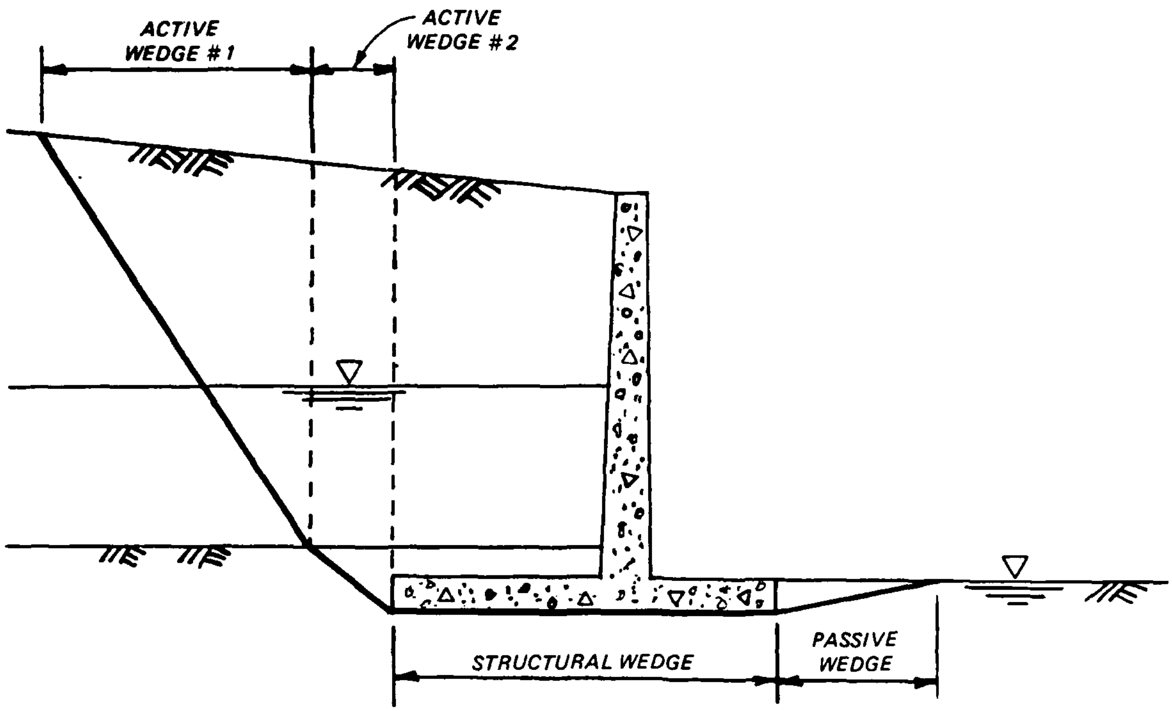


Figure 2. Typical system of wedges

failure surface in Figure 1 into wedges. The base of a wedge is formed from either a section of the failure surface that lies in a single soil layer or along the base of the structure. The interface between any two adjacent wedges is assumed to be a vertical plane which extends from the intersection of the corners of the two adjacent wedges upward to the top soil surface. The base of a wedge, the vertical interface on each side of the wedge, and the top soil surface between the vertical interfaces define the boundaries of an individual wedge.

8. The failure mechanism, as shown in Figure 2, is composed of three types of wedges: a set of active wedges, a single structural wedge, and a set of passive wedges. Each active wedge has a net driving shearing force that exceeds the net available resisting shearing force. This force imbalance results in a net horizontal driving force applied by the active wedge. The base of each active wedge is inclined at an angle which produces the maximum driving force for the wedge's geometry, loading conditions, and developed shear strength properties.

9. The next type of wedge is the structural wedge. If the failure plane for the structural wedge is assumed to coincide with the base of the

structure, the structural wedge will be comprised of the structure and any soil above the base of the structure. If the failure plane for the structural wedge is defined below the base of the structure, the additional soil below the base of the structure and above the failure plane will also be included in the structural wedge.

10. The structural wedge may add to the resisting or driving forces which act on the system of wedges. Whether the structural wedge exerts a driving or resisting force depends on the base slope of the structural wedge and on the loads applied to the structural wedge.

11. The last type is the passive wedge. Each passive wedge has a net available resisting shearing force that exceeds the net driving shearing force. This force imbalance results in a net horizontal resisting force applied by the passive wedge. The base of each passive wedge is inclined at an angle which produces the minimum resisting force for the geometry, loading conditions, and developed shear strength properties of the wedge.

12. Depending on the geologic conditions of the foundation material, the total failure surface or parts of the failure surface may be constrained. The inclination of some of the failure planes or the starting elevation of the failure planes adjacent to the structure may be known due to natural constraints at the site. Conditions which warrant the predetermination of parts of the failure surface include bedding planes or cracks in a rock foundation as shown in Figure 3.

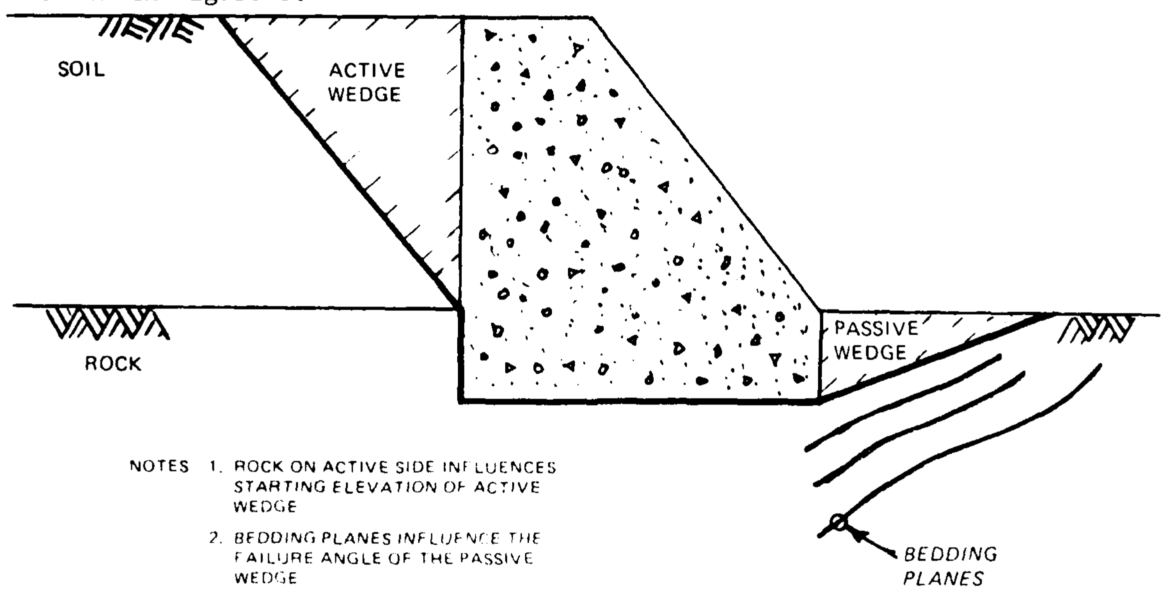


Figure 3. Predetermined failure surface

13. Usually an iterative procedure is needed to find the critical failure surface. For an assumed factor of safety, the inclination of the base of each wedge is varied to produce a maximum driving force for an active wedge or a minimum resisting force for a passive wedge. The assumed factor of safety affects the critical inclination of the base of each wedge. The factor of safety is varied until a failure surface is produced with a set of driving forces equal to the resisting forces. The failure surface resulting from this procedure will be the most critical failure surface. A more detailed explanation of this iteration procedure and conditions which affect the inclination of the failure planes is provided further into this report.

14. The analytical procedures previously discussed are employed in the computer program CSLIDE, and are set forth in ETL 1110-2-256. This ETL established new design criteria for assessing the sliding stability of concrete structures based on a limit equilibrium approach. ETL 1110-2-256 was released by the Office, Chief of Engineers, to replace ETL 1110-2-184 which used a shear-friction concept. The development of the governing wedge equation used in ETL 1110-2-256 and implemented in CSLIDE is presented in the next section.

PART III: DEVELOPMENT OF THE GOVERNING WEDGE EQUATION

Definition of Factor of Safety

15. The limit equilibrium analysis procedures described in ETL 1110-2-256 are based on presently accepted geotechnical principles that consider the shear strength of soil and rock in the analysis. *A factor of safety is* applied to the factors which affect the sliding stability and are known with the least degree of certainty; these factors are the material strength properties.

16. A state of limiting equilibrium is said to exist when the resultant of the applied shear stresses is equal to the maximum shear strength along a potential failure surface. Therefore, a structure is stable against sliding for a potential failure surface when the applied shear stress is less than the available shear strength along that surface. The ratio of the maximum shear strength to the applied shear stress along a potential failure surface is defined as the factor of safety (FS)* as shown in Equation 1.

$$FS = \frac{\tau_F}{\tau} \tag{1}$$

where

τ_F = maximum shear strength

τ = applied shear stress

17. By rearranging Equation 1, the shear stress necessary to maintain the wedge system in equilibrium is equal to the maximum shear strength divided by the factor of safety (Equation 2).

$$\tau = \frac{\tau_F}{FS} \tag{2}$$

This ratio of maximum shear strength to FS may be thought of as the degree of shear strength mobilized.

---

* For convenience, symbols and abbreviations are listed in the Notation (Appendix D).

Assumptions and Simplifications of Analysis

18. Two simplifications used in the derivation of the sliding equations are:

a. The interface between adjacent wedges is a vertical plane.

b. The failure surface is composed of linear segments.

19. The fundamental assumptions used in the derivation of the sliding equations are:

a. The FS is defined by Equation 1.

b. The sliding mechanism can be adequately represented by a two-dimensional analysis.

c. The maximum available shear resistance is defined by the Mohr-Coulomb failure criteria.

d. The assumed failure surface is kinematically possible.

e. Force equilibrium is satisfied; moment equilibrium is not considered.

f. The shearing force acting parallel to the interface of any two wedges is negligible. There is no interaction of vertical effects between wedges.

g. The FS for each wedge is identical.

h. The effects of displacements on the magnitudes of active and passive forces developed are not considered.

i. There can be only one structural wedge because concrete structures transfer significant shearing forces across vertical internal boundaries.

Sign Convention

20. The equations for the sliding stability of a general wedge system are derived using a right-hand coordinate system as shown in Figure 4. The origin of each wedge is located at the lower left corner of the wedge as shown in Figure 5. The x-axis is horizontal and the y-axis is vertical.

21. Axes which are tangent (t) and normal (n) to a failure plane are inclined at an angle (α) to the +x- and +y-axes. A negative angle is formed from a clockwise rotation of the axes. A positive angle is formed from a counterclockwise rotation of the axes.

22. Figure 5 illustrates the sign convention and angle orientation for a typical i^{th} wedge.

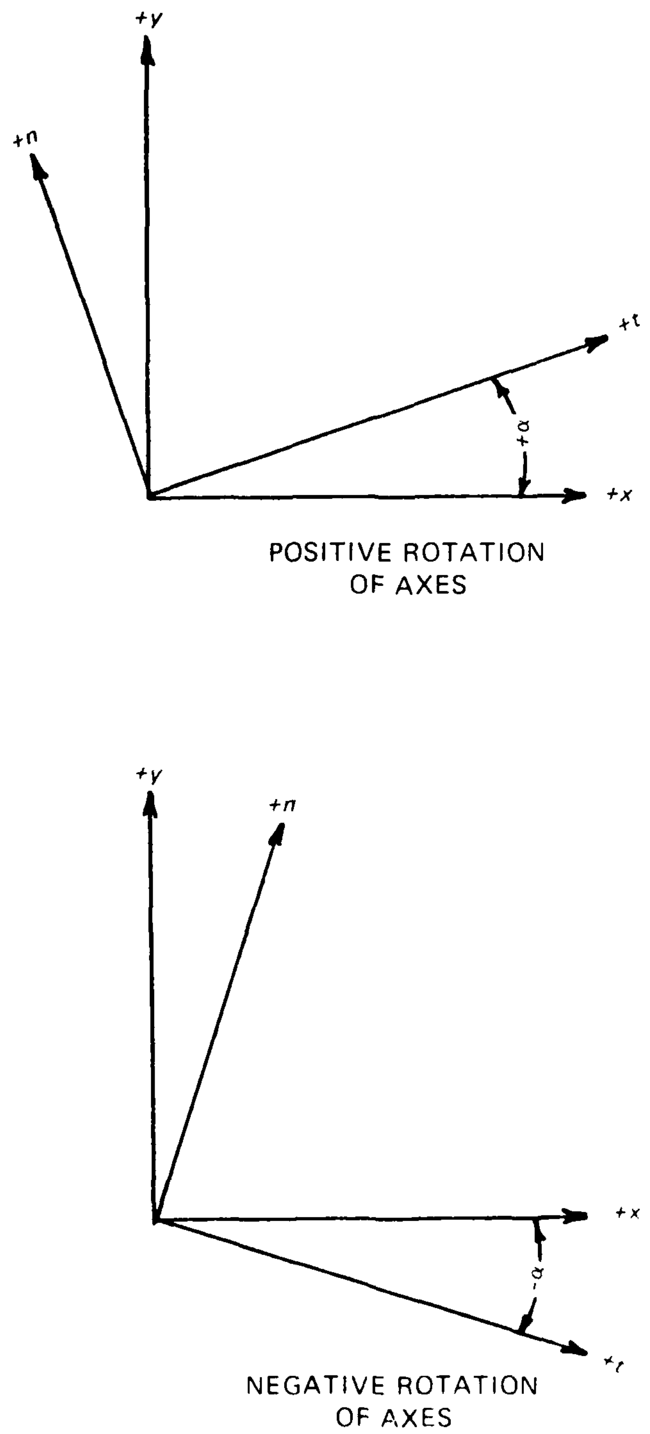


Figure 4. Sign convention

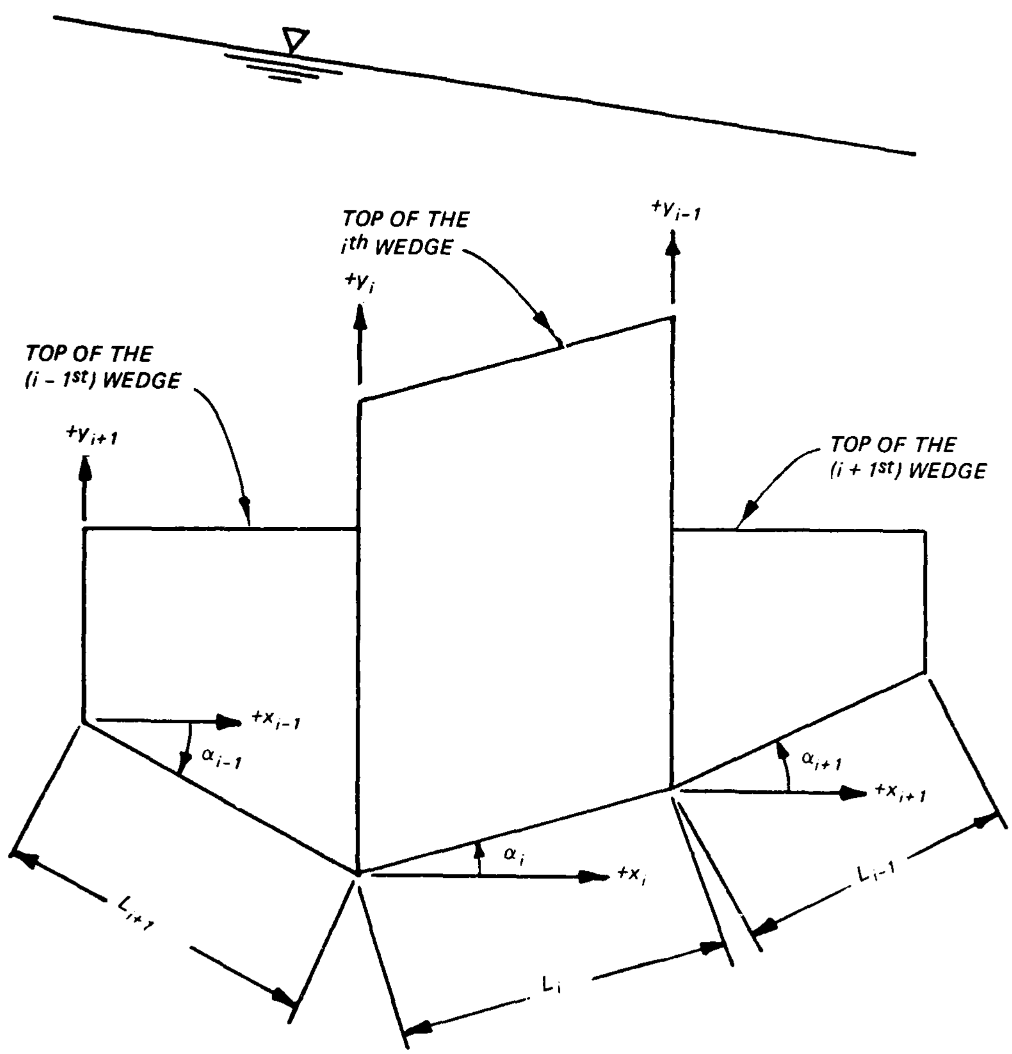


Figure 5. Geometry of typical i^{th} wedge and adjacent wedges

Forces on Typical Wedge

23. The forces acting on a wedge may be applied by external loads to the wedge system or by internal loads within the wedge system. Internally applied loads consist of the weights of the wedges and the contact boundary forces which exist between adjacent wedges. All other applied loads are considered to be external loads.

24. Figure 6 illustrates the possible loads that can exist on a typical i^{th} wedge. Except for the P and W forces, all other forces applied to the wedge in Figure 6 are external loads. The P forces include the effects of water forces and earth forces that exist at the interface of adjacent wedges.

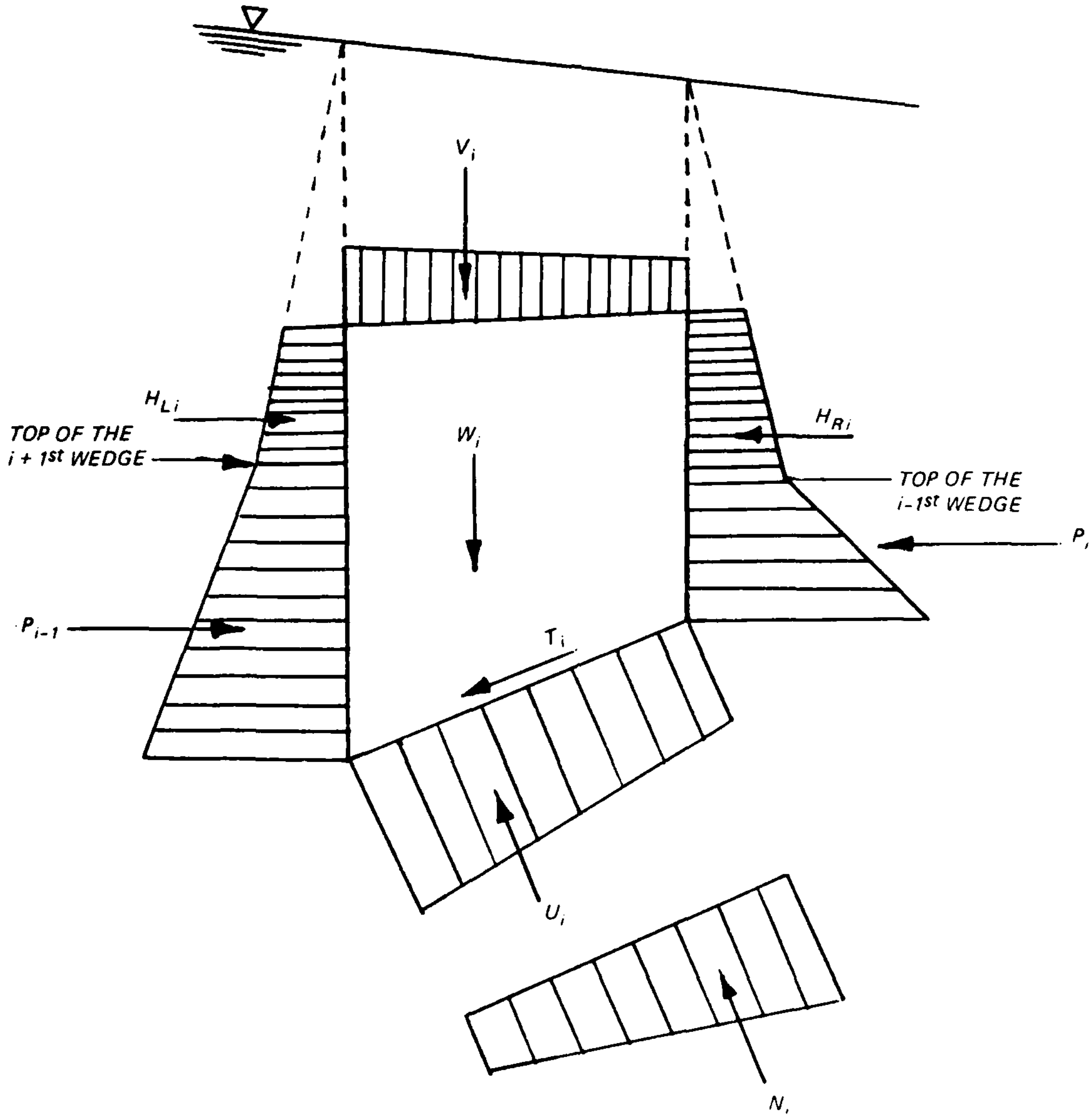


Figure 6. Distribution of pressures and resultant forces acting on a typical wedge

The presence of water may also induce external horizontal and vertical loads if the water level is above the top of a wedge or above the top of an adjacent wedge.

25. Listed below are the various loads that can exist on a typical wedge:

a. The V forces consist of applied surcharge loads, induced loads due to earthquake accelerations, and water loads.

b. The H forces consist of applied point loads, induced loads due to earthquake accelerations, and water loads.

c. The W force is the weight of the wedge.

d. The P forces are the earth forces and water forces that exist between adjacent wedges.

e. The U force is the resultant uplift force due to seepage or hydrostatic pressures.

f. The T force is the applied shearing force.

g. The N force is the normal force necessary for the wedge to remain in equilibrium.

Derivation of Governing Wedge Equation

26. The initial step in the derivation of the governing wedge equation is to sum forces in the tangential and normal directions as seen in ETL 1110-2-256. To accomplish this, the free body diagram must be drawn and the applied forces resolved into their normal and tangential components as shown in Figure 7. Only force equilibrium is satisfied in this procedure; moment equilibrium is not considered. Therefore, only the magnitudes of the applied forces are considered and not their locations. Summing forces in the normal direction provides the equation for the normal force.

$$\Sigma F_n = 0$$

$$0 = N_i + U_i - W_i \cos \alpha_i - V_i \cos \alpha_i - H_{Li} \sin \alpha_i + H_{Ri} \sin \alpha_i - P_{i-1} \sin \sigma_i + P_i \sin \alpha_i \qquad (3)$$

$$N_i = (W_i + V_i) \cos \alpha_i - U_i + (H_{Li} - H_{Ri}) \sin \alpha_i + (P_{i-1} - P_i) \sin \alpha_i$$

Next, summing forces in the tangential direction provides the equation for the applied shearing force.

$$\Sigma F_t = 0$$

$$0 = -T_i - W_i \sin \alpha_i - V_i \sin \alpha_i + H_{Li} \cos \alpha_i - H_{Ri} \cos \alpha_i + P_{i-1} \cos \alpha_i - P_i \cos \alpha_i \qquad (4)$$

$$T_i = (H_{Li} - H_{Ri}) \cos \alpha_i - (W_i + V_i) \sin \alpha_i + (P_{i-1} - P_i) \cos \alpha_i$$

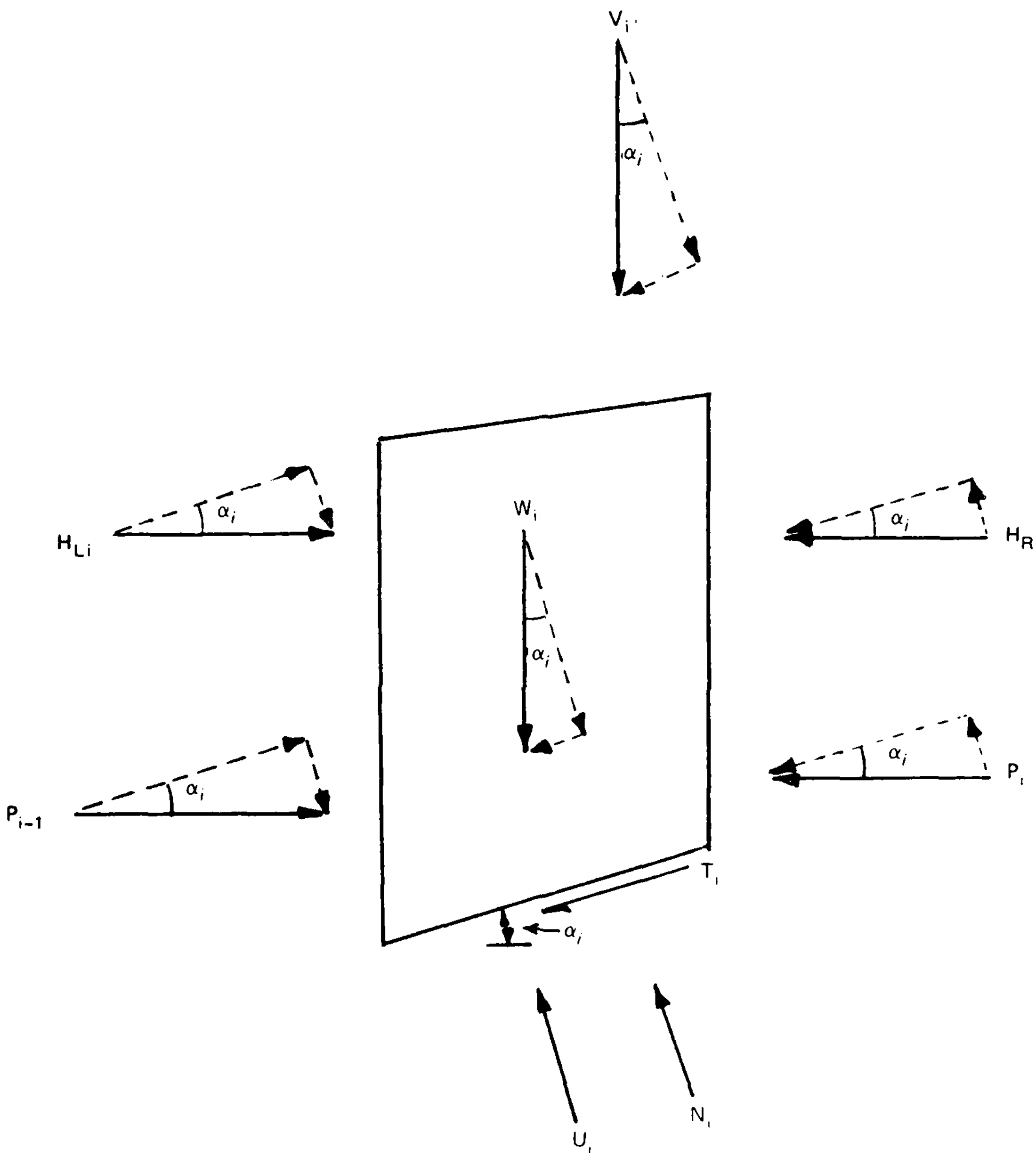


Figure 7. Free body diagram of i^{th} wedge

27. The limit equilibrium analysis considers a material to be on the verge of failure. The maximum shear strength of a material is assumed to be defined by the Mohr-Coulomb failure criteria as shown in Figure 8. Thus, the maximum shearing force available to resist sliding along the base of a wedge is defined by the Mohr-Coulomb failure criteria as

$$T_F = N_i \tan \phi_i + c_i L_i \quad (5)$$

where

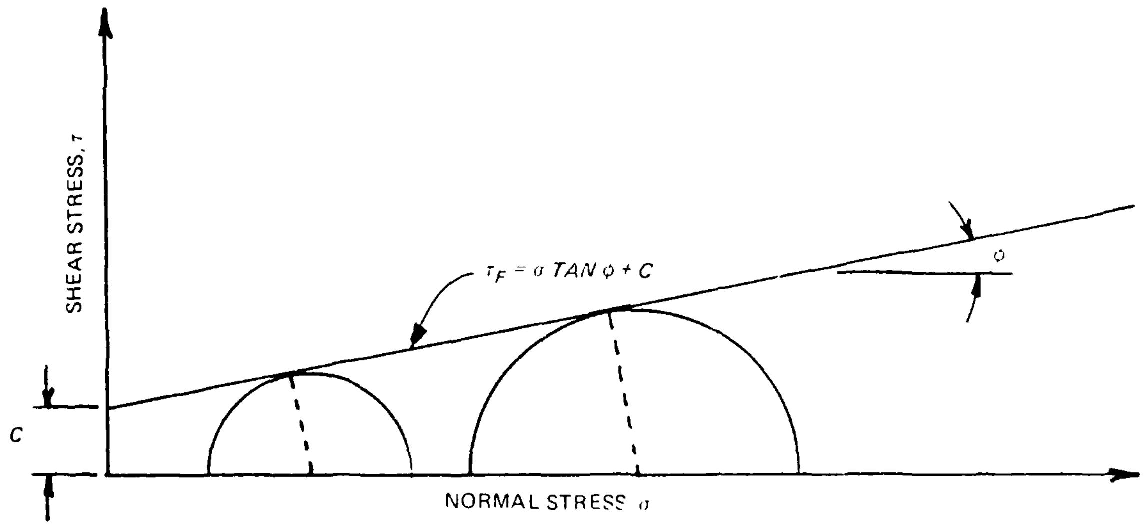
T_F = maximum shearing force available to resist sliding

N_i = applied normal force on the base of the i^{th} wedge

ϕ_i = internal friction angle of the soil along the base of the i^{th} wedge

c_i = average cohesion of the soil along the base of the i^{th} wedge

L_i = length of the base of the i^{th} wedge



where

τ_F = the maximum shear strength at failure

σ = the applied normal stress

ϕ = the internal friction angle of the soil

c = the cohesion of the soil

Figure 8. Mohr-Coulomb failure criteria

28. The governing wedge equation can now be derived by combining the definition of the FS with the definition of the maximum shearing force along the base of a wedge as defined by the Mohr-Coulomb failure criteria. By combining Equations 1 and 5, the FS is now equal to

$$FS_i = \frac{T_F}{T_i} = \frac{N_i \tan \phi_i + c_i L_i}{T_i} \tag{6}$$

Inserting the equation for the normal force (Equation 3) and the equation for the applied shearing force (Equation 4) into Equation 6 yields an equation for the FS in terms of the forces applied to an individual wedge.

$$FS_i = \frac{(W_i + V_i) \cos \alpha_i - U_i + [(H_{Li} - H_{Ri}) + (P_{i-1} - P_i)] \sin \alpha_i \tan \phi_i + c_i L_i}{[(H_{Li} - H_{Ri}) + (P_{i-1} - P_i)] \cos \alpha_i - (W_i + V_i) \sin \alpha_i} \tag{7}$$

Rearranging Equation 7 to solve for the net internal wedge force, $P_{i-1} - P_i$, yields the governing wedge equation for an individual wedge.

$$P_{i-1} - P_i = \frac{[(W_i + V_i) \cos \alpha_i - U_i + (H_{Li} - H_{Ri}) \sin \alpha_i] \frac{\tan \phi_i}{FS_i} - (H_{Li} - H_{Ri}) \cos \alpha_i + (W_i + V_i) \sin \alpha_i + \frac{c_i}{FS_i} L_i}{\cos \alpha_i - \sin \alpha_i \frac{\tan \phi_i}{FS_i}} \tag{8}$$

29. Equation 8 is the form of the governing wedge equation implemented in CSLIDE and discussed in the remainder of this report.

30. A negative value of the difference, $P_{i-1} - P_i$, indicates the applied shearing forces acting on the i^{th} wedge exceed the shearing forces resisting sliding along the base of the wedge. A positive value of the difference, $P_{i-1} - P_i$, indicates the applied shearing forces acting on the i^{th} wedge are less than the shearing forces resisting sliding along the base of the wedge.

31. The assumed direction of the applied shearing force T_i implies failure is occurring from left to right. Because of this assumption, the active earth force side is located to the left of the structural wedge and the

passive earth force side is located to the right of the structural wedge.

32. In the remainder of this report, any reference to the sign of a force, as it relates to the direction of failure, will be based upon the assumption that failure will occur from left to right.

33. The governing wedge equation has two unknowns: the difference, $P_{i-1} - P_i$, and the FS. For a system with a total of n wedges there will be 2n unknowns. Recall, one of the assumptions of this method is the system of wedges act as an integral failure mechanism. For this to be true, the safety factors for all the wedges must be identical. Thus, for a system of n wedges there will be n equations with $n + 1$ unknowns.

34. An additional equation is supplied by satisfying overall horizontal equilibrium, $\Sigma F_H = 0$, for the entire system of wedges.

$$\sum_{i=1}^{n} P_{i-1} - P_i = 0 \tag{9}$$

where the boundary forces P_o and P_n are set equal to zero.

35. Usually an iterative process is required to determine the FS that places the system of wedges in equilibrium. The net horizontal earth force, $P_{i-1} - P_i$, for each wedge is calculated using Equation 8 with a trial FS. All of the $P_{i-1} - P_i$ forces are summed and if Equation 9 is satisfied, the FS is obtained that places the system of wedges in equilibrium.

PART IV: ANALYSIS PROCEDURE

General Iteration Procedure

Procedure for a fixed failure surface

36. A general procedure for analyzing a system of wedges with predetermined base inclinations using the governing wedge equation is summarized below:

- a. Assume a potential failure surface based on the geologic conditions of the foundation and configuration of the substructure.
- b. Divide the assumed failure surface into the appropriate number of wedges with one structural wedge. The interface between adjacent wedges is defined by a vertical plane.
- c. Isolate each wedge in a free body diagram, applying all forces which act on the wedge.
- d. Assume an FS for the system.
- e. Calculate the difference, $P_{i-1} - P_i$, for each wedge using the governing wedge equation.
- f. Sum the differences, $P_{i-1} - P_i$.
- g. For the system of wedges to be in equilibrium, the sum of the differences calculated in step f should equal zero.
- h. Based on the sum of the differences, revise the value of the assumed FS. If the sum is negative, the FS is lower than assumed. If the sum is positive, the FS is greater than assumed.
- i. Repeat steps e through h until equilibrium is achieved.
- j. Other failure surfaces may be analyzed by returning to step a.

37. The above procedure assumes the total failure surface is determined prior to performing the iteration procedure which finds the FS that produces a state of equilibrium.

Procedure for a variable failure surface

38. An alternate procedure is necessary when the failure surface is unknown. The failure surface is determined by assuming an initial FS and varying the inclinations of the bases of the wedges. The failure angle of each active wedge is varied to produce a maximum driving force and the failure angle of each passive wedge is varied to produce a minimum resisting force. Once the failure surface is established, the iteration procedure is similar to

the procedure for a fixed failure surface given in the previous section.

39. The general iteration procedure for obtaining the FS for a variable failure surface is given below:

a. Assume an FS.

b. Depending on the geologic conditions of the foundation and configuration of the substructure, predetermine any portions of the failure surface which are not variable. The starting elevations of the wedges adjacent to the structural wedge may also need to be predetermined (Part VI).

c. Beginning with the wedge closest to the structural wedge on the active side (Figure 9), choose a trial inclination for the base of this wedge. The wedge closest to the structural wedge will also be the wedge in the lowest soil layer.

d. For this trial inclination, draw a free body diagram of the wedge applying all forces which act on the wedge.

e. Calculate the difference, $P_{i-1} - P_i$, for the wedge.

f. Assume a new trial inclination and repeat steps d and e. Depending on whether or not the second trial inclination

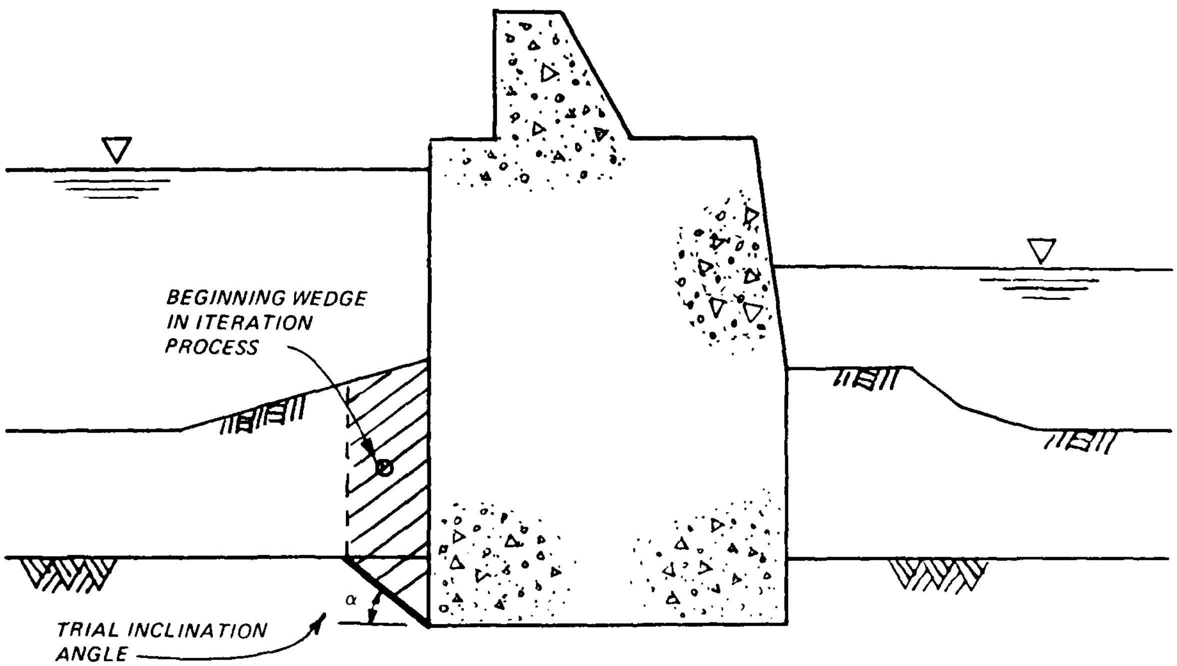


Figure 9. Beginning wedge in iteration process

produced a larger or smaller difference (absolute value), vary the inclination until a maximum magnitude of the difference, $P_{i-1} - P_i$, is found.

g. Move out from the structural wedge to the next wedge. The outer wedge will begin where the inner wedge ended. Repeat steps d through f. Do this for all the active wedges.

h. Draw a free body diagram of the structural wedge applying all forces which act on the wedge. Calculate the difference, $P_{i-1} - P_i$, on the wedge.

i. Repeat steps c through g for the wedges on the passive side except iterate to find a minimum magnitude of the difference, $P_{i-1} - P_i$, for each wedge.

j. Sum up the $P_{i-1} - P_i$ differences. For the system to be in equilibrium, the sum should equal zero.

k. If the sum of the differences does not equal zero, revise the value of the trial FS. If the sum is negative, the FS is lower than assumed. If the sum is positive, the FS is greater than assumed.

l. Repeat steps c through k until the sum of the $P_{i-1} - P_i$ differences equals zero.

CSLIDE Procedure

40. CSLIDE uses the previously described iteration procedure for a variable failure surface to calculate the critical failure surface which has the minimum FS. The manner in which CSLIDE varies the FS and the failure angles of the wedges to locate this critical failure surface and minimum FS is described in this section. The convergence criteria employed by CSLIDE which indicates when the solution has converged to a critical one is also discussed in this section.

Factor of safety

41. CSLIDE uses an upper and lower bound for the FS to select a trial FS to be used in the first two iterations. An upper bound of 1.5 and a lower bound of 0.5 for the FS are the default values, but the user has the option to select his own values for the upper and lower bounds.

42. In the first iteration, the average of the upper and lower bounds is used as the trial FS. After the first iteration, if the sum of the $P_{i-1} - P_i$ differences is negative, the lower bound is used in the second iteration. If the sum of the $P_{i-1} - P_i$ differences is positive, the upper bound is used in the second iteration. For any subsequent iterations, a trial

FS is extrapolated from or interpolated between the present and previous factors of safety to achieve a state of horizontal equilibrium.

43. For possible problems concerning the use of input values for the upper and lower bounds of the FS, refer to Part VI.

Failure angles

44. The base inclination angles for both the single and multiple plane analyses (Part VI) vary initially in 5-deg increments. When a maximum or a minimum force for a wedge is bound by two angles, the increment is reduced.

45. The failure angles for a single plane analysis are calculated to the nearest 0.001 deg. The failure angles for a multiple plane analysis are calculated to the nearest 0.1 deg to reduce the amount of computational work.

46. The single and multiple plane analyses differ in the accuracy used to calculate the failure angles. For a single plane analysis, all wedges on a particular side, active or passive, will have the same failure angle. Therefore, a minimum resisting or a maximum driving force is sought for a particular plane and not for each individual wedge. For this analysis, the failure angles are calculated to the nearest 0.001 deg. For a multiple plane analysis, the failure angle of each wedge is varied to find a maximum driving or minimum resisting force for that wedge. This analysis requires more computational work than does the single plane analysis. Consequently, the failure angles for the multiple plane analysis are calculated to the nearest 0.1 deg.

Convergence criteria

47. The solution is assumed to have converged when the absolute value of the sum of the $P_{i-1} - P_i$ differences for any iteration is less than or equal to 0.001 kips.*

Water Pressures

48. The user may use any of the following methods to account for the uplift effects due to the presence of water:

a. Water pressures may be entered at the ends of each wedge.

b. Hydrostatic pressures may be calculated at the ends of each wedge.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

c. An uplift force may be entered for the structural wedge.

d. Uplift pressures at the ends of each wedge may be calculated by the line of creep method.

An explanation of each method is provided in the following paragraphs.

Input uplift pressures

49. Water pressures may be entered at the ends of each wedge, and the program will calculate an uplift force acting on the base of each wedge.

Hydrostatic pressures

50. Hydrostatic pressures will be calculated at the ends of each wedge if hydrostatic conditions exist or if the program is instructed to calculate hydrostatic pressures. The program will use the hydrostatic pressures to calculate an uplift force which acts on the base of each wedge.

Input uplift force

51. An uplift force that acts on the base of the structural wedge may be specified. The uplift forces on the remaining wedges may be calculated by any of the other methods.

Line of creep

52. Seepage pressures are calculated using the line of creep method. The line of creep method assumes a linear distribution of head loss along the shortest seepage path. The shortest seepage path is the distance in the soil around the wetted perimeter of the structural wedge.

53. Bernoulli's equation for laminar flow defines the total head (h) measured from an arbitrary datum as

$$h = z + \frac{P_w}{\gamma} \tag{10}$$

where

z = elevation head of an arbitrary point

P_w = pressure at an arbitrary point

γ = unit weight of water

54. In groundwater flow, the value of the total head changes from point to point in the soil medium because of a loss of energy due to the viscous resistance within the individual pores. To account for this loss of energy, Bernoulli's equation is taken as

$$z_1 + \frac{P_{w1}}{\gamma} = z_2 + \frac{P_{w2}}{\gamma} + h_L \qquad (11)$$

where h_L is the head loss between points 1 and 2.

55. Referring to Figure 10, the pressure at an arbitrary point P may be calculated by using Equation 11. By taking the datum at the elevation of the tailwater, point 1 at the elevation of the headwater, and point 2 at point P, Equation 11 reduces to

$$H + 0 = z_p + \frac{P_p}{\gamma} + h_{L_p}$$

$$P_p = \left(H - z_p - h_{L_p}\right)\gamma$$

where

P_p = pressure at point P

H = total head loss, headwater elevation minus tailwater elevation

z_p = elevation head of point P, elevation of datum minus elevation of point P

h_{L_p} = total head loss incurred going to point P

56. The head loss to an arbitrary point P is calculated as

$$h_{L_p} = H\left(\frac{\text{Distance around wetted perimeter to point P}}{\text{Total seepage distance around wetted perimeter}}\right)$$

57. From Figure 10, the head loss incurred in going from point 1 to point 2 is

$$h_{L_p} = H\left(\frac{abc}{abcd}\right)$$

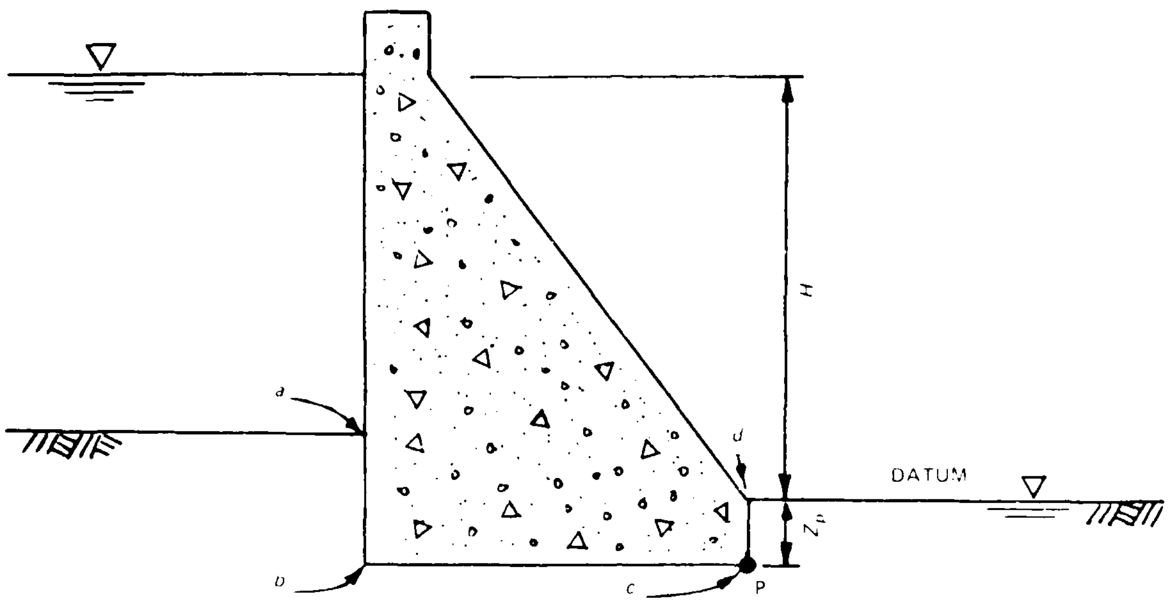


Figure 10. Pressure at an arbitrary point

Limitations of Program

58. The main limitation of the program is the restriction that the number of wedges formed must equal the number of soil layers. As discussed earlier in the procedure for a variable failure surface, a wedge is first formed in the lowest soil layer on each side of the structural wedge, and the base of a wedge is contained entirely in a single soil layer. The program progresses up the soil layers until a wedge is formed in the top soil layer.

59. Once the base of a wedge has been established in a soil layer, the remaining soil profile beyond the base of the wedge is ignored. The program does not realize when the base of a wedge in an upper soil layer intersects a lower soil profile. This is shown in Figure 11.

60. Another restriction of the program is that no portions of one soil profile may coincide with another soil profile. All soil profiles must be separated by some small distance. An example of how to model a problem which has a conflict with overlapping layers is shown in Figure 12.

61. Since CSLIDE uses the governing wedge equation as derived earlier, failure is assumed to occur from left to right. The iteration procedure contained in CSLIDE is also based upon this assumption. Therefore, when entering a problem, the active side must always be on the left and the passive side must always be on the right.

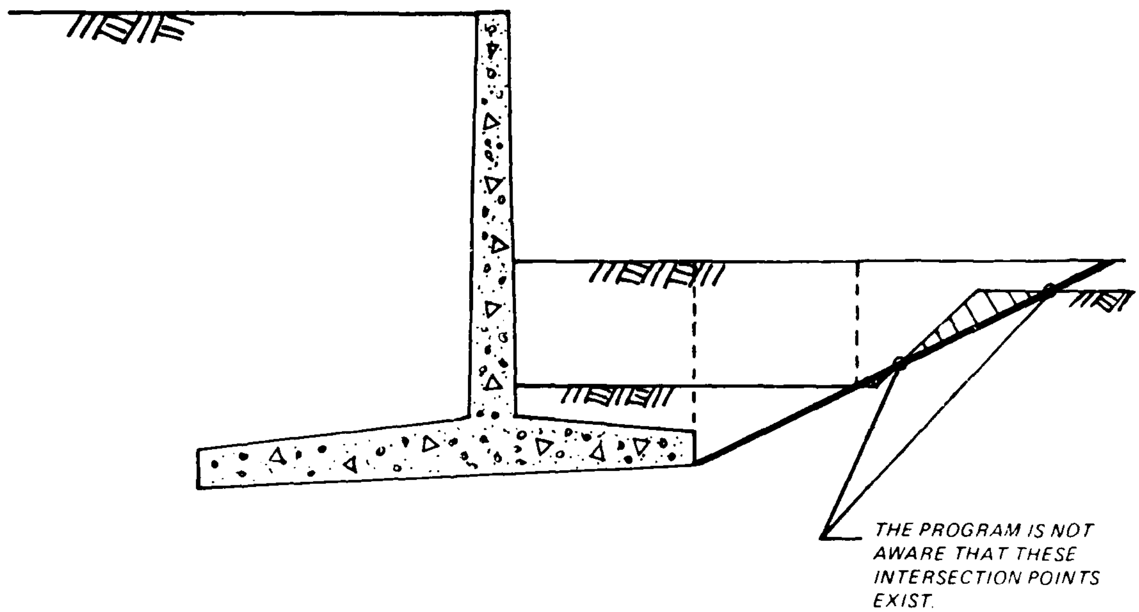
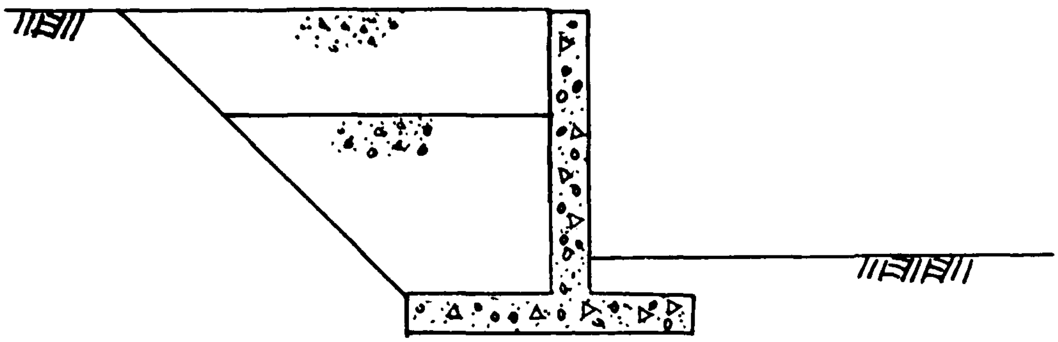
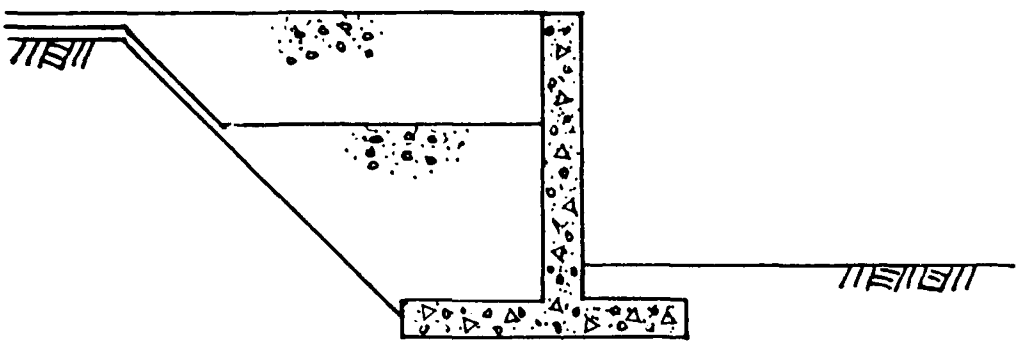


Figure 11. Conflict of wedge in upper soil layer with lower soil layer



SOIL LAYERS CANNOT OVERLAP

a. Actual soil geometry



SOIL LAYERS MUST BE SEPARATED

b. Correct modeling of soil layers

Figure 12. Modeling several overlapping soil layers

PART V: CAPABILITIES OF PROGRAM CSLIDE

62. CSLIDE can analyze stability problems with a variety of soil geometries, structure geometries, and loading conditions. A general soil/structure system that can be analyzed by CSLIDE is shown in Figure 13.

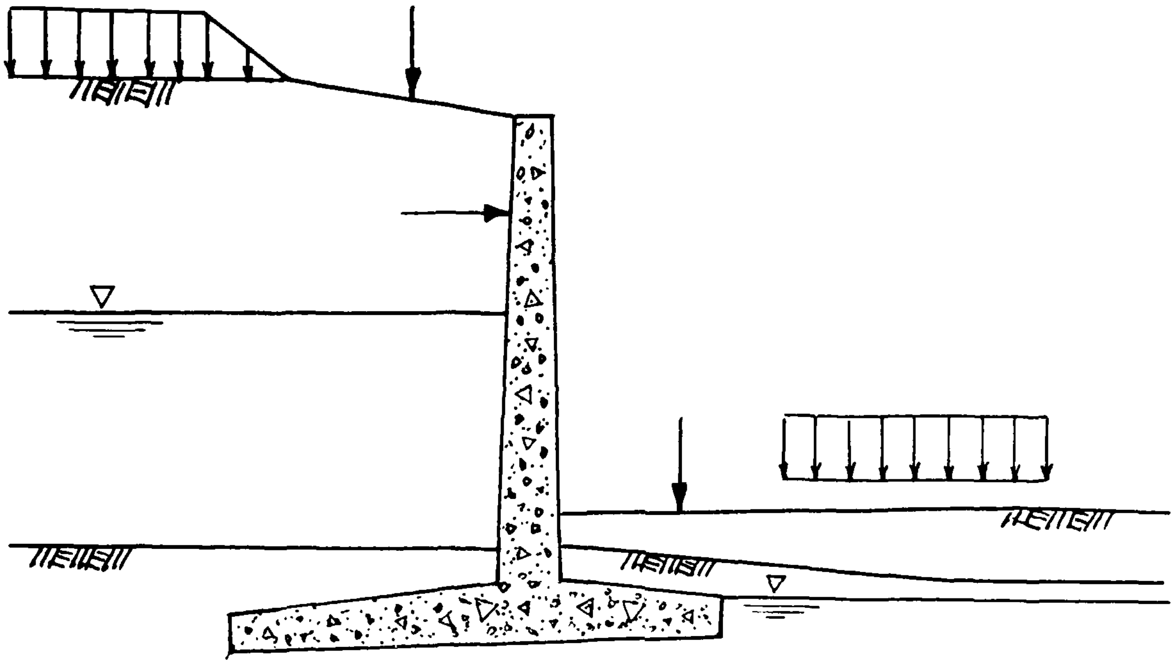


Figure 13. General soil/structure system

63. An outline of the capabilities of CSLIDE follows as Figure 14. For a more detailed discussion of the various options available, refer to Part VI. For a detailed discussion of how to enter the data refer to Part VIII.

I. Input Data

A. Structural Wedge

1. Structure may be composed of up to 20 points.

2. Elevation of the wedge-structure intersection on the active side of the structure may be specified. The elevation must always be at or above the lower left corner of the structure and below the top of the lowest soil layer on the active side.

3. Percent of the base in compression may be specified.

4. Bottom of the structural wedge must be defined by one plane.

B. Left-Side Soil and Right-Side Soil

1. A maximum of 5 soil layers on each side of the structural wedge may be entered with a maximum of 10 points describing each layer.

2. The right-side soil is always considered the passive side and the left-side soil is always considered the active side.

3. All left-side soil elevations at the structure must be above the lower left corner of the structure. If only one soil layer is entered, it may be at the elevation of the lower left corner of the structure.

4. All right-side soil elevations at the structure must be above the lower right corner of the structure. If only one soil layer is entered, it may be at the elevation of the lower right corner of the structure.

5. All left-side soil elevations at the structure must be above the elevation of the wedge structure intersection.

6. Each soil layer has its own angle of internal friction, cohesion, and unit weight.

C. Properties of Soil Below Structure. The properties of the soil below the structure are specified by an angle of internal friction and an adhesion value.

Figure 14. Capabilities of CSLIDE (Sheet 1 of 4)

D. Methods of Analysis

1. Single plane. All wedge angles on a particular side are the same.

2. Multi-plane. Wedge angles may vary on a particular side.

3. Angles may vary from +85 to -85 deg. Thus, layers that slope down and away from the base of the structure may be handled by the program.

E. Water

1. Water elevation may be specified on the left and right sides.

2. The water height may be greater on either side.

3. Methods of computing uplift.

   a. Pressures may be input at the top and bottom of each wedge and at five points along the base of the structure. The pressure is assumed to vary linearly between the input points.

   b. Hydrostatic pressure calculations may be specified or if there is no difference in head, hydrostatic pressures are automatically calculated.

   c. An uplift force may be specified for the structural wedge. An uplift force may be specified when using any of the methods for computing seepage pressures.

   d. Line of creep method along the shortest seepage path may be used.

F. Input Wedge Angles. Angles ranging from +85 to -85 deg may be specified for any of the soil wedges. If an angle is input for the structural wedge, it must extend a plane at or below the base of the structure. The structural wedge would include the additional soil below the structure and the angle would define the new sliding plane. Thus, it is possible to examine a plane below the base of the structure for deep-seated sliding.

G. Earthquake Loads. Horizontal and vertical seismic coefficients may be specified.

Figure 14. (Sheet 2 of 4)

H. Factor of Safety

1. An upper and lower bound may be specified for the FS to aid in the interpolation for new factors of safety.

2. A ratio of the passive FS to the active FS may be specified.

I. Vertical Loads

1. Maximum of 10 line loads.

2. Maximum of 10 strip loads.

3. Maximum of 10 triangular loads.

4. Maximum of 10 ramp loads.

5. Two uniform loads (one on the active side, one on the passive side).

J. Horizontal Loads. As many as necessary may be placed on any wedge.

II. Data Entry

A. Prompting Sequence

B. Terminal Input with Keywords

C. Input From File with Keywords

III. Editing

A. Edit by Sections of Data

B. Edit Using Keywords

C. Edit from File

1. Rerun current data with modifications.

2. Enter new problem.

IV. Output

A. Echoprint of Input Data

B. View All Iterations as Solution Converges

Figure 14. (Sheet 3 of 4).

C. Final Results

1. Vertical and horizontal loads on all wedges.

2. Water pressures at the vertices of all wedges.

3. Failure angles of all wedges.

4. Weights of all wedges.

5. Total and submerged lengths of all wedges.

6. Uplift forces on all wedges.

7. Net force on all wedges.

8. Factor of safety.

D. Graphics

1. Plot of input.

2. Plot of failure surface.

3. Plot of each wedge with all forces applied.

4. Plot of convergence of solution.

Figure 14. (Sheet 4 of 4)

PART VI: DISCUSSION OF PROGRAM INPUT

64. This section will elaborate upon each option available to the user. The purpose of each option, the conditions which warrant the use of each option, and the information required to use each option will be discussed.

Factor of Safety Ratio

65. The user is allowed to enter a ratio of the FS for the passive side to the FS for the active side. The program will try to maximize the active earth force using a trial FS. Once the active earth force is maximized, the trial FS is multiplied by the ratio entered. The program uses this new FS and attempts to minimize the passive earth force.

66. The movement of the soil required to develop a full passive earth force is about 5 to 10 times the movement required to develop a full active earth force. Since a maximum driving force will exist before the full resisting force is developed, it would be desirable to use only a partial amount of the full passive resistance in an analysis. The passive resistance may be reduced by applying a greater FS to the passive wedges than is applied to the active wedges. This is accomplished by using an FS ratio greater than one.

67. For an FS ratio of one, both the active and passive wedges will use the same trial FS. When a state of equilibrium is obtained, the active FS and passive FS will be equal. The value of the FS when the failure mechanism is in equilibrium for a FS ratio of one will be called the balance point. The balance point is shown in Figure 15.

68. As shown in Figure 15, an increase in the passive FS will cause a decrease in the active FS. A reduction in the passive FS will cause an increase in the active FS. This is the typical trend of the active and passive factors of safety for equilibrium conditions.

69. A linear relationship does not exist between the FS ratio and the value of the active FS. If results were compared for FS ratios of 2 and 10, the active FS obtained would not differ by a factor of 5. This can be seen from the shape of the curve in Figure 15.

70. Also, a linear relationship does not exist between the passive FS and the forces exerted by the passive wedges. The passive FS may be increased by a certain factor, but the passive earth forces would not decrease by this same factor.

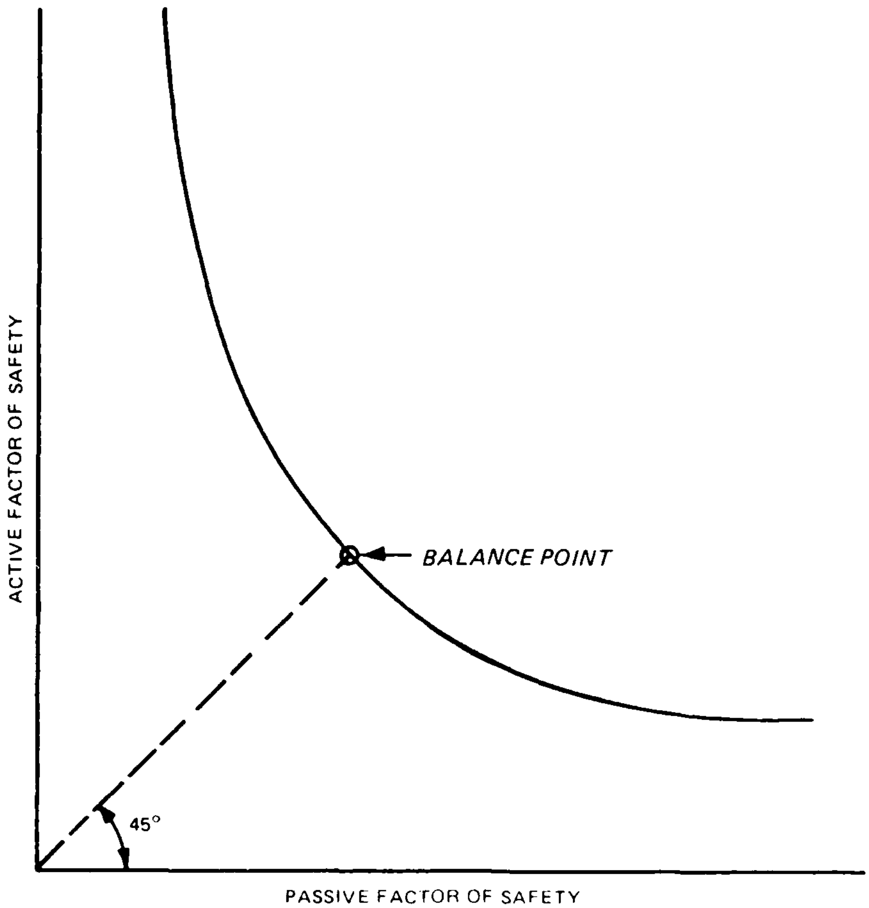


Figure 15. Relationship of the passive to active factors of safety for equilibrium conditions

71. Since the reduction of the passive earth forces is the primary concern, the $P_{i-1} - P_i$ forces acting on the passive wedges obtained for a certain FS ratio should be compared to the passive forces obtained for an FS of one. An FS of one applied to the passive wedges will produce full passive earth forces. By comparing the passive forces obtained for various FS ratios to the passive forces obtained for an FS of one, the actual decrease in the passive resistance may be measured.

Active Wedge-Structure Intersection Elevation

72. Depending upon the condition and the type of foundation material, the starting elevation of the active wedge adjacent to the structural wedge

may need to be adjusted. Initially, the starting elevation of this wedge is assumed to be at the elevation of the lower left corner of the structure. If needed, the user has the option to change this starting elevation.

73. If the structure is founded in competent rock, the rock will not exert an active force on the structure when the structure begins to move. Therefore, the failure plane on the active side should begin at the top of the rock foundation. If water exists above the base of the structure, the horizontal component of the water load on the structure below this wedge elevation should be included in the analysis as an external load, because it is not included in the interslice forces. An example of this is shown in Figure 16.

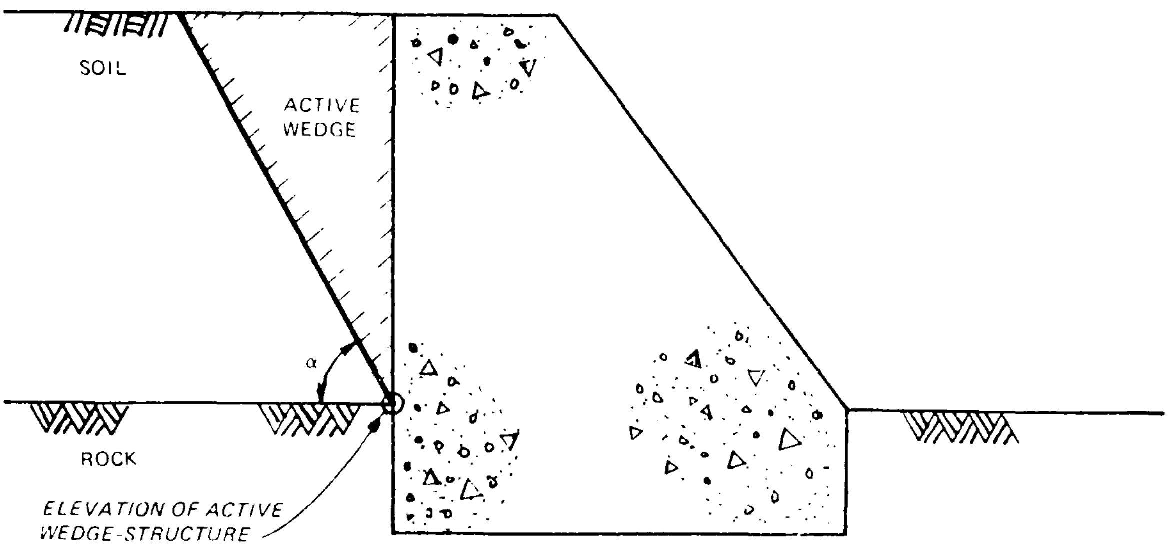


Figure 16. Elevation of the active wedge-failure angle at left side of structure

Input Wedge Angles

74. The inclination of the failure planes may be predetermined by factors such as loading conditions and the geologic structure of the foundation. The failure angle of any wedge may be specified to account for these conditions.

75. A condition which warrants the user determining the inclination of a failure plane would be a structure founded in rock which has discontinuities such as bedding planes.

Factor of Safety Boundaries

76. CSLIDE uses an upper and lower bound to select the trial FS to be used in the first two iterations in search of a critical failure surface. Initially, the upper boundary for the FS is set to 1.5 and the lower boundary is set to 0.5. The program begins the iteration process with the average of the upper and lower boundaries. Depending on whether the sign of the sum of the forces on the system is negative or positive, the lower or upper boundary is used, respectively, for the next iteration. For each iteration afterward, a new trial FS is computed by extrapolating from or interpolating between the present and previous factors of safety to produce horizontal equilibrium.

77. The user may set an upper and lower boundary for the FS. The user may wish to do this if the final FS is known approximately. This will eliminate excessive oscillations and cause the solution to converge more rapidly.

78. The user may also want to adjust the FS boundaries for other reasons. The solution process will halt if either the solution has not converged within 30 iterations, an FS greater than 100 is computed, or a trial FS less than or equal to 0.2 is computed. By shifting the boundaries of the FS, these conditions might be eliminated and a final solution obtained.

79. If the same value is entered for both the upper and lower boundaries of the FS, results are reported for that value of the FS. Earth forces for a particular FS may be obtained in this manner.

Percent of Base in Compression

80. For some load cases, the vertical component of the resultant applied loads will lie outside the kern of the base area. When this happens, a portion of the structural wedge will not be in contact with the foundation material. CSLIDE allows the user to control the percent of the base of the structure that is in compression to reflect the interaction between overturning and sliding behavior.

81. Therefore, it may be advantageous to perform an overturning analysis prior to the sliding analysis. From the overturning analysis, the uplift force on the base of the structure and the percent of the base in compression may be calculated.

82. The reduction of the contact length between the base of the structure and the foundation material reduces the adhesive force resulting from the contact between these two surfaces. The frictional resistance between the base of the structure and the foundation material is unaffected by the reduction in the base contact length.

Seismic Loading

83. Earthquake accelerations may be accounted for by using the seismic coefficient (pseudo-static) method. Both horizontal and vertical seismic coefficients are multiplied by the total weight of a wedge. The resulting horizontal and vertical loads are applied to the wedge as additional static loads.

84. The total weight of a wedge includes the weight of all soil contained in the wedge, all vertical surcharge loads applied to the wedge, and the weight of any water contained within the wedge.

85. When water is above ground, the static pressure which it exerts against a wall can be increased or decreased by seismic action. The force exerted by water above ground due to seismic action may be accounted for by using Westergaard's equation found in EM 1110-2-2200.* The forces developed must be applied by the user as horizontal loads.

86. Guidance for the selection of appropriate values of the horizontal seismic coefficient may be found in ER 1110-2-1806.** As stated in ETL 1110-2-256, the vertical earthquake acceleration is normally neglected, but if included in the analysis, it can be taken as two thirds of the horizontal coefficient.

Single-Plane Failure Analysis

87. A single-plane analysis uses a single plane on both the active and passive sides as shown in Figure 17. Since a single-failure plane is formed on each side of the structural wedge, one failure angle will be associated

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* Headquarters, Department of the Army. 1958 (Sep). "Gravity Dam Design," EM 1110-2-2200, Washington, DC.

** Headquarters, Department of the Army. 1983 (May). "Earthquake Design and Analysis for Corps of Engineers Projects," ER 1110-2-1806, Washington, DC.

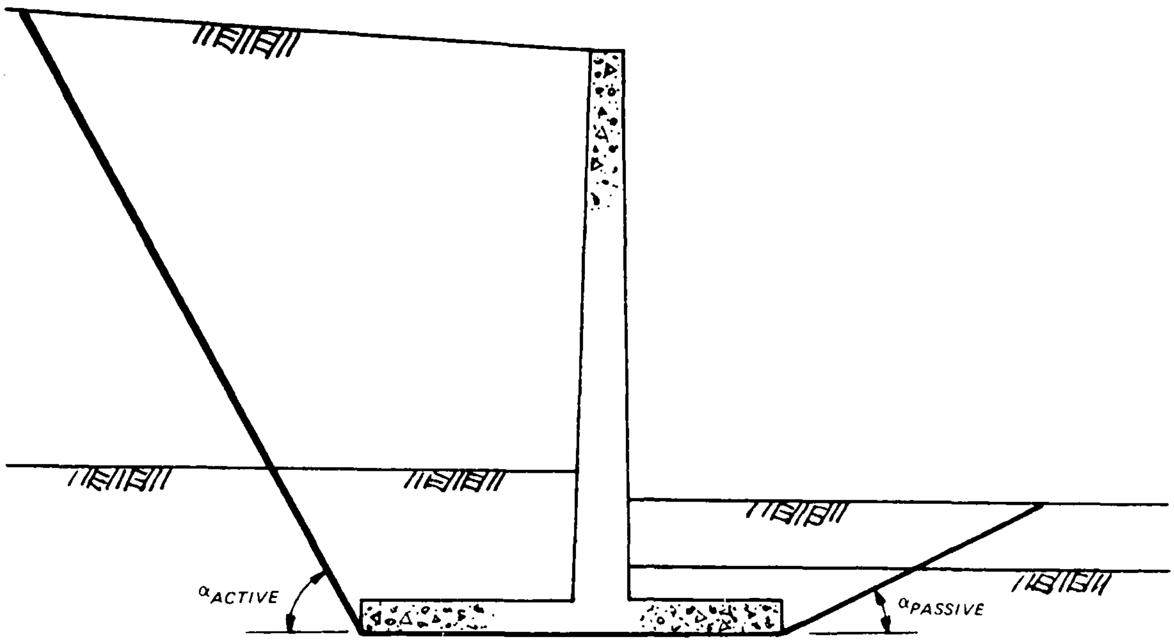


Figure 17. Single-plane failure analysis

with the active wedges and another failure angle will be associated with the passive wedges.

Multiple-Plane Failure Analysis

88. As shown in Figure 18, a multiple-plane failure analysis forms a failure surface on both the active and passive sides of the structural wedge, which is composed of segments with varying failure angles. A different failure plane is formed in each soil layer. The inclination of the failure plane depends on the soil properties associated with that segment of the failure surface and on the loading conditions of the system.

89. The shear strength of a failure surface is a combination of the shear strengths of the individual wedges which form the failure surface. The shear strength of each segment of the failure surface is calculated using the soil properties of the soil layer in which the segment is contained.

90. For a system with a single soil layer, the multiple-plane failure analysis will yield results identical to those obtained by the single-plane failure analysis.

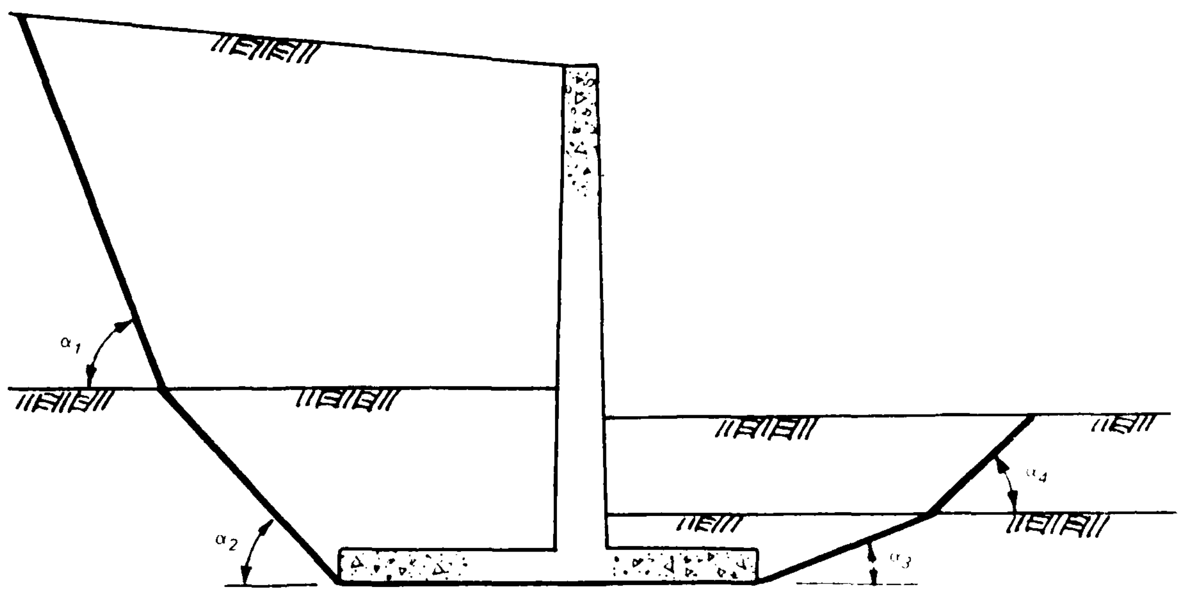


Figure 18. Multiple-plane failure analysis

PART VII: DISCUSSION OF OUTPUT

Output Table

91. This section discusses each item listed in the output table. The horizontal forces applied to both the left and right sides of each wedge and the vertical forces applied to each wedge are discussed. The individual components that comprise each load are given. Other pertinent information required to perform a hand check of the computations, such as the failure angle, the weight, and length of each wedge, and the uplift force applied to each wedge, are also discussed.

Horizontal loads

92. The horizontal loads applied to both the left and right sides of each wedge are printed. Each value will be the summation of any input external horizontal loads, any horizontal load due to the presence of water next to the wedge, and any induced horizontal load due to horizontal earthquake acceleration.

93. The horizontal loads printed are always positive. Loads on the left side act toward the right and loads on the right side act toward the left.

Vertical loads

94. The vertical loads printed will be the summation of any applied vertical loads, any vertical load due to the presence of water above the wedge, and any induced vertical load due to vertical earthquake acceleration.

95. The structural wedge may have an additional load due to soil contained within the structural wedge. Any soil contained above the base of the structure is reported as a vertical load.

96. If an input angle is applied to the structural wedge to shift the base of the structural wedge downward, the soil included in the structural wedge below the base of the structure is reported as a vertical load.

Water pressures

97. Water pressures are printed at the vertices of each wedge. As discussed in Part IV, these pressures may be entered by the user or calculated by the program. The program will calculate hydrostatic water pressures or water pressures using the line of creep. If an uplift force was entered on the structural wedge, the uplift value will be reported.

Failure angles

98. Failure angles are printed for each of the wedges. These angles may be entered by the user or calculated by the program. Failure angles for a single-plane failure analysis are calculated to the nearest 0.001 deg. Failure angles for a multiple-plane failure analysis are calculated to the nearest 0.1 deg to reduce the amount of computations required for this method.

Length of wedge

99. Both the total length and the submerged length of each wedge are printed. The total length is used when calculating the weight of a wedge. The submerged length is used when calculating the uplift force on a wedge.

Weight of wedge

100. The weight of each wedge other than the structural wedge includes only the weight of the soil contained within the wedge. The weight of the structural wedge consists only of the weight of the structure, and does not include the weight of any soil contained within the structural wedge.

Uplift force

101. The uplift force for each wedge is reported and includes the uplift effect due to water along the submerged length of the wedge. The user may enter an uplift force on the structural wedge instead of allowing CSLIDE to calculate pressures.

Net force

102. The net force for each wedge is reported and is an indication of whether the wedge exerts a driving or resisting force. A negative net force implies the forces tending to cause sliding are greater than the forces resisting sliding. A positive net force indicates the forces tending to cause sliding are less than the forces resisting sliding.

103. The program assumes the active side is always on the left and the passive side is always on the right. An active wedge will have a negative net force and a passive wedge will have a positive net force.

104. There are conditions, such as applying a horizontal earthquake load, that may cause the sign of the net force on a passive wedge to be negative. In effect, this means the passive wedge is pulling on the remaining wedges. When this condition occurs, the net force on the passive wedge is set to zero in the program and a message is printed. By setting the net force of the passive wedge to zero, any driving force exerted by the passive wedge is ignored.

Sum of forces

105. The sum of the net forces on each wedge should equal zero if the system is in equilibrium. The program has a tolerance of 0.001 kip for this sum. There are several cases where the final solution will have a nonzero sum of the net forces. These conditions are discussed in paragraph 112.

106. A negative sum implies that the final FS will be less than the present one. A positive sum implies that the final FS will be higher than the present one.

Factor of safety

107. The solution has converged to a final FS when the absolute value of the sum of the net forces on each wedge is less than or equal to 0.001 kip. This will be the minimum FS and the failure surface calculated will be the most critical one.

108. The calculated FS must be greater than 0.2 and less than 100. If a trial FS does not lie between these bounds, the iteration procedure will halt and the results of the last completed iteration will be given as the final results.

109. If a large value for the FS is obtained, the active and passive sides of the problem should be reversed and the problem reanalyzed. A large FS may indicate sliding is in the opposite direction from what was originally assumed.

110. Allowable factors of safety are given in ETL 1110-2-256.

Output Messages

111. There are several informative messages that may appear in the output table. These messages refer to the following conditions:

- a. If an input angle is used for the structural wedge, a message will be printed giving the intersection point of the line inclined along this angle, with the opposite end of the structural wedge.
- b. If, in the iteration process, the value of a failure angle for any wedge falls below -85 or exceeds +85 deg, the failure angle is fixed at ±85 deg. A message is printed which identifies the angle or angles.
- c. If, in the iteration process, a failure plane cannot be formed in a soil layer without exceeding the boundaries of the problem, a message is printed identifying the wedge or wedges in

which this occurs. The end of the wedge is fixed at the outer boundary of the problem.

Possible Solutions

112. The final FS reported may be for one of the five following conditions:

a. If a trial FS drops below 0.2, a message is printed and the results are reported for the last completed iteration.

b. If a trial safety factor goes above 100, a message is printed and the results for the last completed iteration are reported.

c. If the solution does not converge within 30 iterations, a message is printed and the results of the last iteration are reported.

d. If the solution converges within 30 iterations, the results of the final analysis are reported.

e. If the sum of the forces for any two successive iterations does not vary by more than 0.001 kip, the message, "Stationary Solution" is printed. This message will occur if the upper and lower boundaries of the FS are equal.

113. If a, b, or c occur, the program might calculate a final FS if the user changes the FS boundaries as discussed in Part VI.

Temporary Solutions

114. The user is given the option to view each iteration as the program searches for the critical FS. In some cases it may be helpful to view the intermediate results to see how the solution converged.

PART VIII: INPUT GUIDE

Source of Input

115. Input data may be supplied from a prepared data file or from the user's terminal during execution. If the data are input from the terminal, the user may enter data by following a prompting sequence or by using key command words.

Data Format

116. All input data, whether supplied from a data file or from the terminal, are read in free field format. In addition:

- *a*. Data items must be separated by one or more blank spaces. Commas are not allowed as delimiters.
- *b*. Integer numbers must be in nondecimal form.
- *c*. Real numbers may be in decimal form, nondecimal form, or E format.

Data Entry from the Terminal

Data entry using a prompting sequence

117. This is the recommended method of data entry for the less experienced user. The program "prompts" the user for information by asking questions about both required and optional data. Details of this method and an example are provided in paragraph 129.

Data entry using command words

118. For an experienced user, entering data by command words (keywords) allows more freedom in the order of data entry and requires less time. Information is entered by typing command words and their accompanying data. An example of entering data by this method is presented in paragraph 130.

Data Entry from a File

119. Data may be entered from a data file which has been created prior to the execution of the program. A data file has the same format that is used

when entering data by command words. The user simply types lines of command words and their accompanying data. All lines of data in the data file must be preceeded by a line number. The data file is entered into the program by typing the file name when requested. An example of data entry from a file is given in paragraph 131.

Input Sections

120. Input to the program is divided into the following main sections:

a. Heading.

b. Structural description.

c. Left-side soil description.

d. Right-side soil description.

e. Description of soil below the structure.

f. Method of analysis.

g. Water description.

h. Wedge angle specification.

i. Earthquake conditions.

j. Safety factor ratio.

k. Vertical surcharge loads.

l. Horizontal loads.

m. Termination.

Minimum Required Data

121. Several of the main input sections listed in paragraph 120 must be entered to provide sufficient information to calculate a solution. Referring to paragraph 120, the minimum required sections of input are a through g and m. Sections h through l are optional.

Sign Convention

122. The program uses a right-hand coordinate system. Coordinates may be input using any quadrant or quadrants. Positive angles are taken counter-clockwise from the horizontal and negative angles are taken clockwise from the horizontal. The sign conventions for the various types of loads are shown in Table 1.

Table 1

Units and Sign Conventions

Item	Units	Sign Convention
Horizontal distances	ft	Negative or positive; values increase from left to right
Vertical distances	ft	Negative or positive; values increase from bottom to top
Unit weights	kcf	
Angle of internal friction	deg	
Failure angles	deg	Clockwise (negative), counter-clockwise (positive); angles are rotated from the positive horizontal axis
Cohesion	ksf	
Vertical loads:		
Strip, ramp, triangular, and uniform surcharges	k/ft	Positive; downward
Point/line loads	kips	Positive; downward
Uplift force on structure due to water	kips	Positive; upward
Horizontal loads	kips	Positive; to the right
Earthquake loads:		
Vertical coefficient		Positive; downward
Horizontal coefficient		Positive; to the right
Water pressures	ksf	Positive; upward

Units

123. All data must be entered in the following units:

a. Length, feet.

b. Force, kips.

c. Angles, degrees.

All output is given in the same units as the input. Table 1 shows a list of the units associated with various items of the input.

Input Description

124. Refer to Table 1 for a summary of units and sign conventions.

Input syntax

125. The following is an explanation of the command words, variables, requirements and restrictions for data input. The syntax shown is to be used when entering data from the terminal or a file.

a. The brackets, [ ], indicate the enclosed variable is optional. All optional variables have default values or no values, as listed. (Do not include the brackets when entering the optional variables.)

b. [LN] indicates a line number is to be used in this location only when a data file is being created.

c. Quotation marks indicate the enclosed alphabetic term is to be typed exactly as it appears, but without the quotation marks.

d. If any keyword line has more than one data line required, the additional lines should immediately follow the keyword line.

e. All data items must be separated by one or more blank spaces. Do not separate data with commas or any other character.

Required data description

126. Four sections of the required data must be entered first and in the following order: Heading, Structural information, Left-side soil information, and Right-side soil information.

a. Heading.

(1) Contents (maximum four lines)

[LN] "TITL" TITLE

(2) Description

"TITL" = keyword for the header line

TITLE = any alphanumeric information of user's choice (maximum 70 characters per line)

b. Structural Information.

(1) Keyword line

(a) Content (one line)

[LN] "STRU" IPT GAMC [ANEL] [FL]

(b) Description

"STRU" = keyword for structure information

IPT = number of points describing the structure

GAMC = equivalent unit weight of the structure, kcf

ANEL = elevation of the active wedge failure angle at left side of structure, ft

(DEFAULT is lower left corner of the structure)

FL = percentage of the concrete base of the structure that is in compression; enter a decimal number less than or equal to 1.000 (DEFAULT is 1.000)

(c) Restrictions/conditions

1. If ANEL is entered, it must be at or above the lower left corner of the structure, and must be below the top of the bottom soil layer.

2. If FL is entered, ANEL must also be entered.

(2) Data line

(a) Content (maximum 20 points)

[LN] XC(1) YC(1) XC(2) YC(2)...XC(IPT) YC(IPT)

(b) Description

XC = X-coordinate of a point describing the structure

YC = Y-coordinate of a point describing the structure

(c) Comment: Enter the structure points, starting with the lower left corner and proceeding clockwise as shown in Figure 19.

(d) Restriction: The base of the structure must be represented by a single line. Therefore, any irregularities in the base of the structure must be approximated by a single plane as shown in Figure 20.

c. Left-Side Soil Description.

(1) Keyword line

(a) Content (one line per layer, maximum five layers)

[LN] "SOLT" NLT LPTS PHIL COL GAML STELL

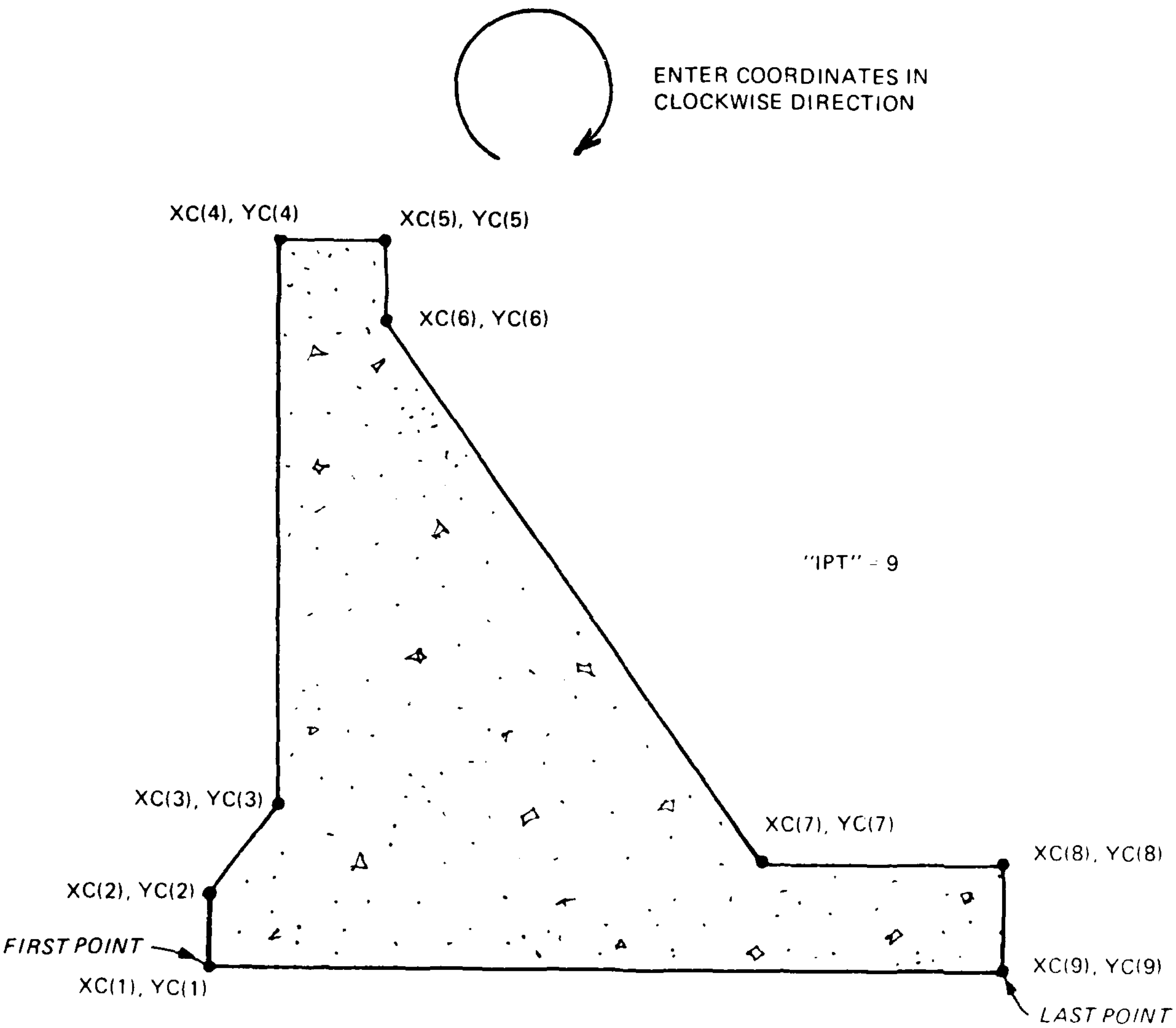


Figure 19. Input of structure coordinates

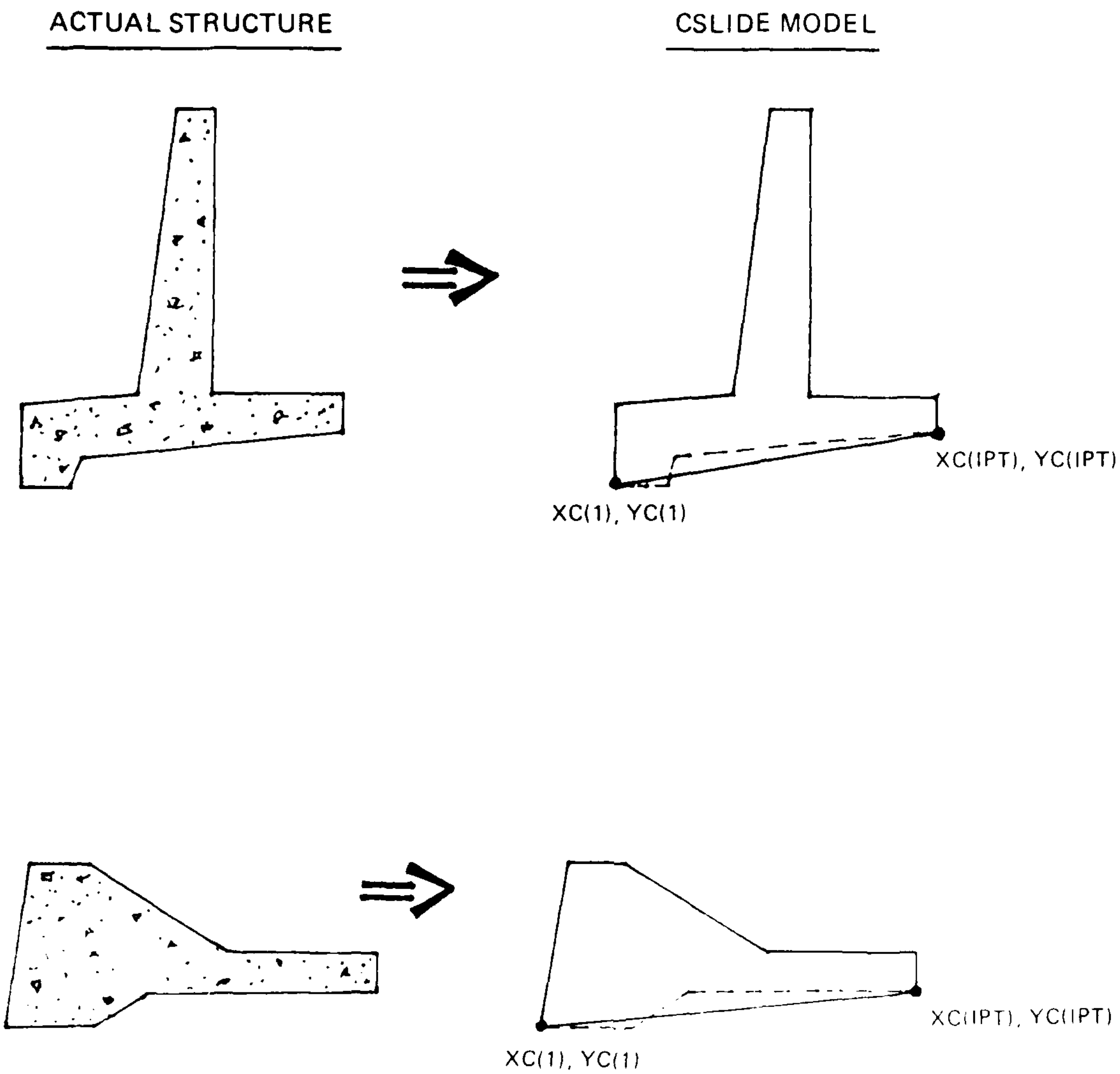


Figure 20. Approximation of irregular base by a single plane

(b) Description

"SOLT" = keyword for left-side soil

NLT = soil layer number (one to five; top to bottom)

LPTS = number of points describing layer (excluding the point at the structure)

PHIL = angle of internal friction of the layer, deg

COL = cohesion of the layer, ksf

GAML = saturated or moist unit weight of the layer, kcf

STELL = elevation of the top of the layer where it meets the concrete structure, ft

(c) Restrictions

1. The soil layers on the left side of the structural wedge always form the active wedges.

2. Figure 21 indicates valid and invalid entries for the left-side soil layers.

(2) Data line

(a) Content (maximum of 10 points per layer; enter for each keyword line)

[LN] XL(1) YL(1) XL(2) YL(2)...

[LN] ... XL(LPTS) YL(LPTS)

(b) Description

XL = X-coordinate of point describing left-side soil layer "NLT"

YL = Y-coordinate of point describing left-side soil layer "NLT"

(c) Comment: The soil layers are defined from top to bottom. Enter the points describing each soil layer from left to right, excluding the point at the structure as shown in Figure 22. Use as many lines as necessary to enter the coordinate points; however, do not split a coordinate pair (X,Y) from one line to the next line.

(d) Note: The soil boundaries are automatically extended 1,000 ft to the left of the first coordinate entered.

d. Right-Side Soil Description.

(1) Keyword line

(a) Content (one line per layer, maximum five layers)

[LN] "SORT" NRT RPTS PHIR COR GAMR STELR

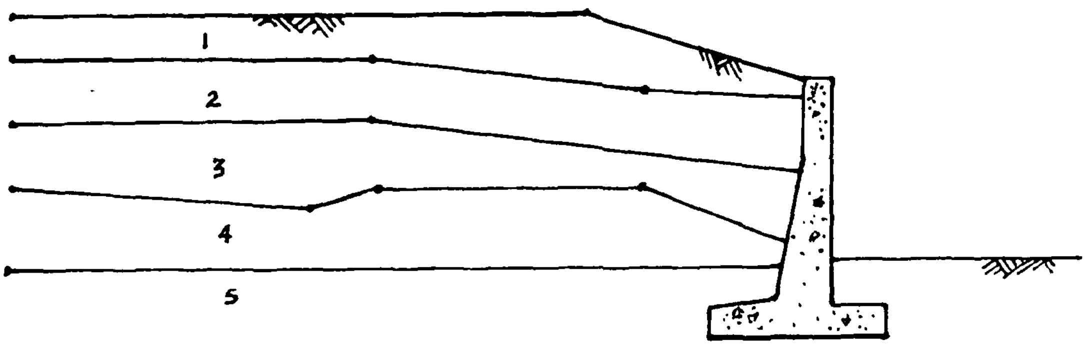
(b) Description

"SORT" = keyword for right-side soil description

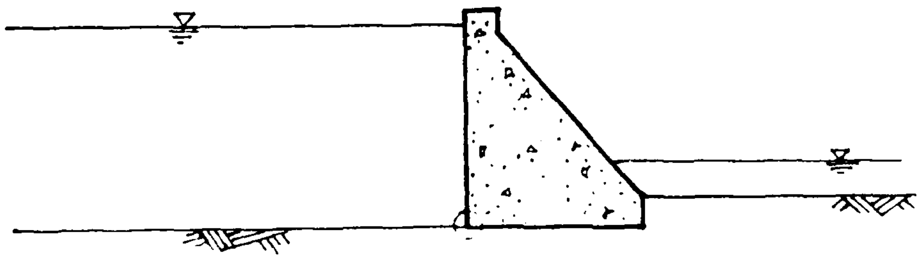
NRT = soil layer numbers (one to five; top to bottom)

RPTS = number of points describing the layer. Exclude the point at the structure.

PHIR = angle of internal friction of the layer, deg



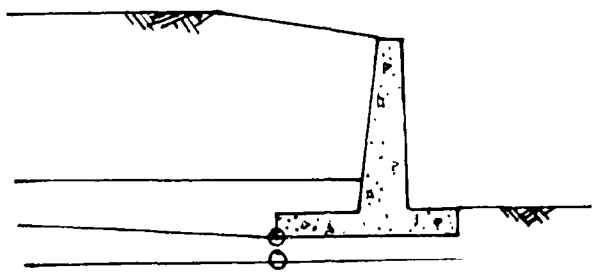
– MAXIMUM OF FIVE LAYERS ABOVE LOWER LEFT CORNER OF STRUCTURE.
– MAXIMUM OF TEN POINTS PER LAYER
– HORIZONTAL OR IRREGULAR LAYERS.



A LAYER IS VALID AT LOWER LEFT CORNER OF STRUCTURE IF IT IS THE TOP LEFT SIDE SOIL LAYER.

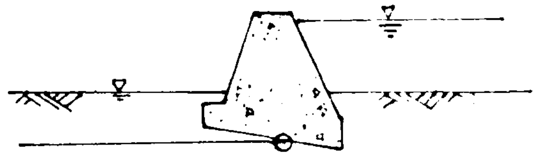
a. Valid entries

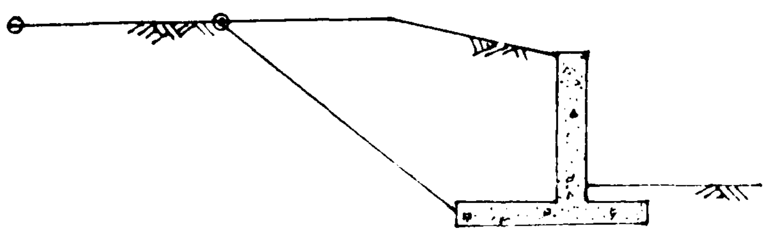
Figure 21. Left-side soil layers (Continued)



LAYERS AT OR BELOW THE LOWER
LEFT CORNER OF THE STRUCTURE
BASE ARE NOT ALLOWED.

LAYERS MAY NOT
INTERSECT THE
STRUCTURE BASE.





LAYER "OVERLAP" IS NOT ALLOWED.
EACH LAYER MUST HAVE UNIQUE
COORDINATE POINTS.

b. Invalid entries

Figure 21. (Concluded)

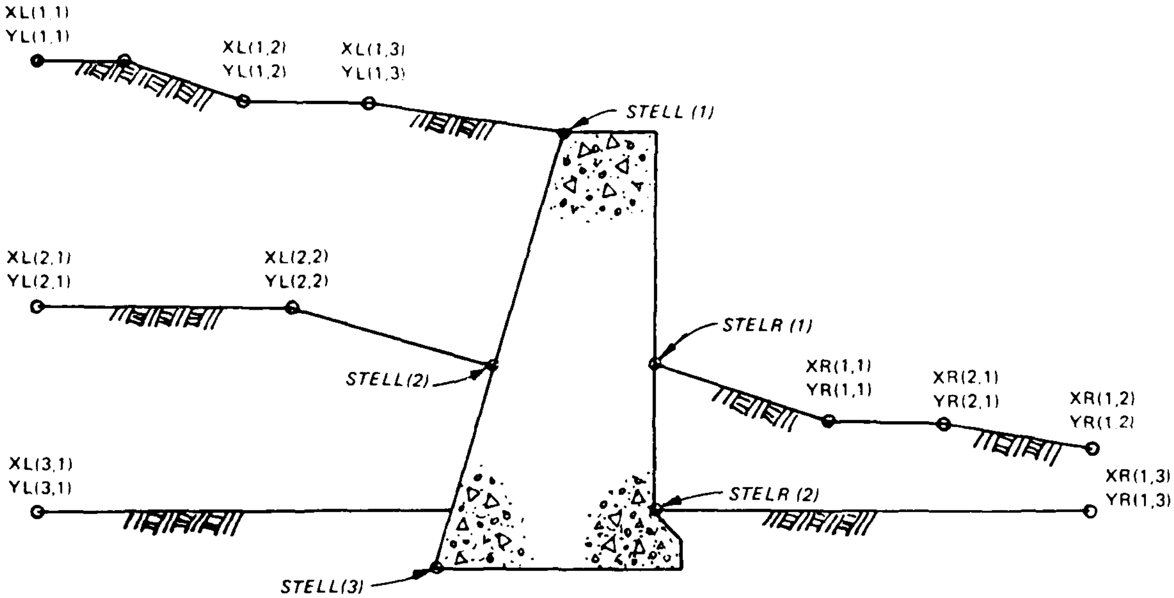


Figure 22. Definition of left- and right-side soil layers

COR = cohesion of the layer, ksf

GAMR = saturated or moist unit weight of the layer, kcf

STELR = elevation of the top of the layer where it meets the structure, ft

(c) Restrictions

1. The soil layers on the right side of the structural wedge always form the passive wedges.

2. Figure 23 indicates valid and invalid entries for the right-side soil layers.

(2) Data line

(a) Content (maximum of 10 points per layer; enter for each keyword line)

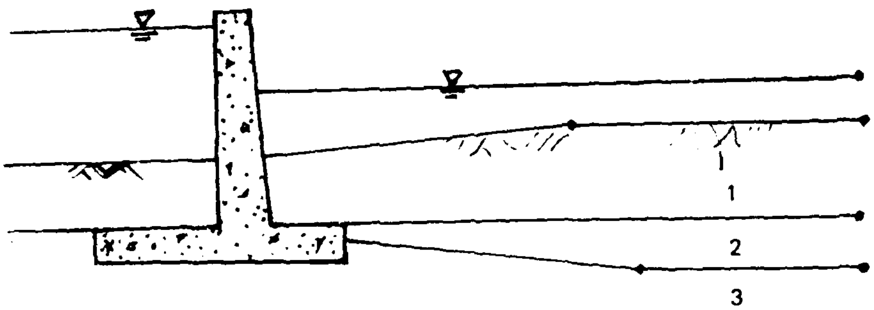
[LN] XR(1) YR(1) XR(2) YR(2)...

[LN] ... XR(RPTS) YR(RPTS)

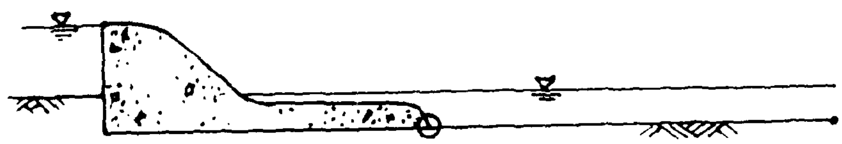
(b) Description

XR = X-coordinate of point describing right-side soil layer "NRT"

YR = Y-coordinate of point describing right-side soil layer "NRT"



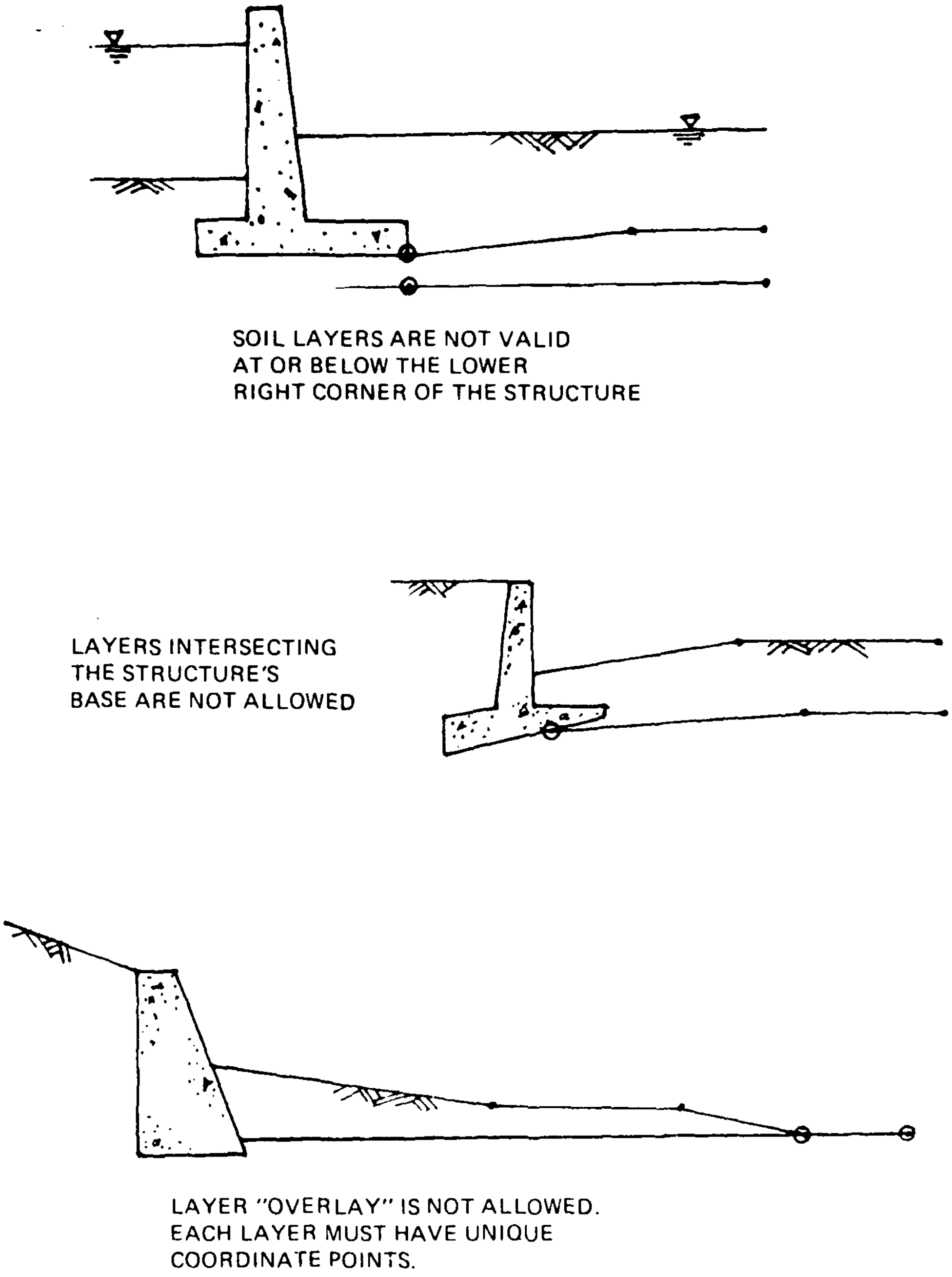
- MAXIMUM OF 5 LAYERS ABOVE THE LOWER RIGHT CORNER OF THE STRUCTURE.
- MAXIMUM OF 10 POINTS PER LAYER.
- HORIZONTAL OR IRREGULAR LAYERS.



- LAYER IS VALID AT LOWER RIGHT CORNER OF STRUCTURE IF IT IS THE TOP RIGHT SIDE LAYER.

a. Valid entries

Figure 23. Right-side soil layers (Continued)



b. Invalid entries

Figure 23. (Concluded)

(c) Comment: The soil layers are defined from top to bottom. Enter the points describing each soil layer from left to right, excluding the point at the structure as shown in Figure 22. Use as many lines as necessary to enter the coordinate points; however, do not split a coordinate pair (X,Y) from one line to the next line.

(d) Note: The soil boundaries are automatically extended 1,000 ft to the right of the last coordinate entered.

127. After the four initial sections of required data have been entered in order, the remaining required sections may be entered in any order. These remaining sections are described in the following paragraphs.

a. Soil Below the Structure.

(1) Content (one line)

[LN] "SOST" PHIC CCS

(2) Description

"SOST" = keyword for the description of the material properties at the interface of the base of the structural wedge and the soil below the structural wedge.

PHIC = angle of internal friction or angle of base friction, deg

CCS = cohesion or adhesion, ksf

(3) Restriction: When more than one type of soil comes into contact with the base, PHIC and CCS should be represented as an average or equivalent value.

(4) Note: If the base of the structure is part of the failure surface, an angle of base friction and an adhesion value would be used. If the failure surface passes below the base of the structure, the material properties of the soil, an angle of internal friction, and a cohesion value would be used.

b. Method of Analysis.

(1) Content (one line)

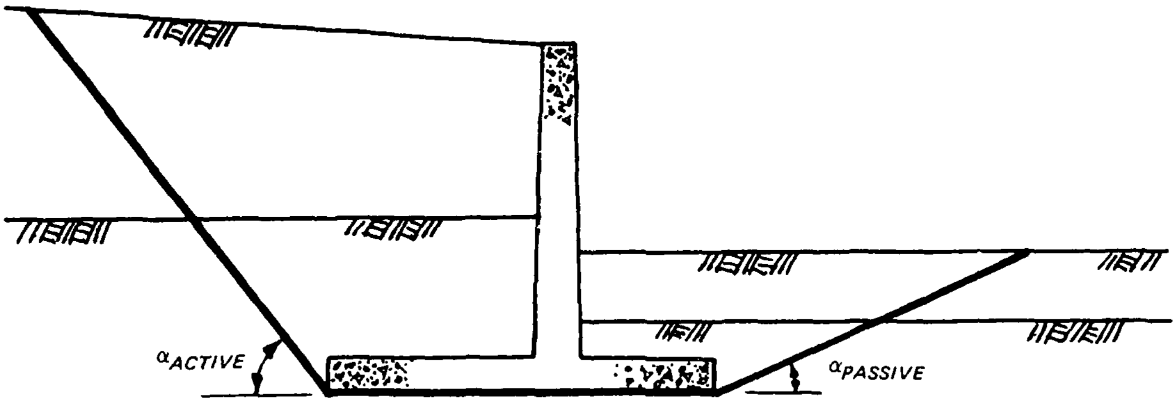
[LN] "METH" MEAN

(2) Description

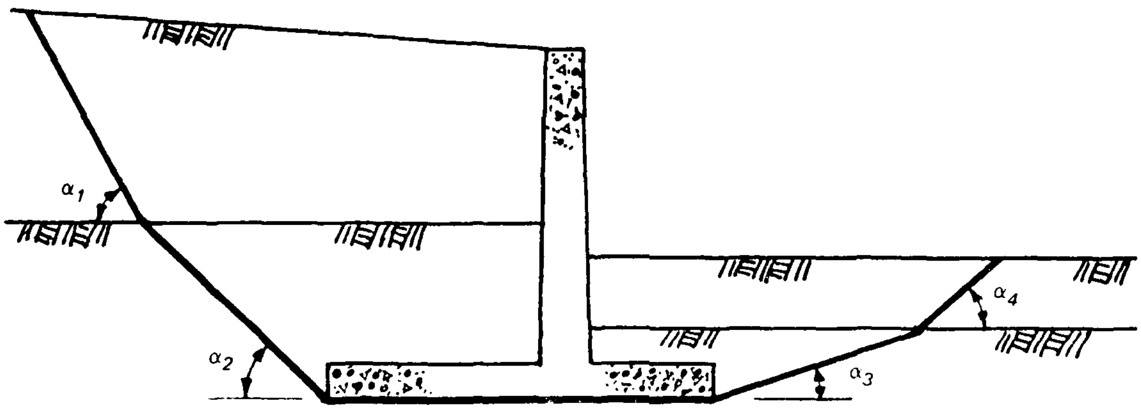
"METH" = keyword for the type of layer analysis to be used

MEAN = 1 for single-plane analysis
= 2 for multi-plane analysis

(3) Comment: In Method 1 analysis, failure angles are calculated to 0.001 ± 0.0005 deg. In Method 2 analysis, failure angles are calculated to 0.1 ± 0.05 deg, to decrease the number of calculations in this method. An example of each method is shown in Figure 24.



a. Single-plane failure analysis



b. Multiple-plane failure analysis

Figure 24. Failure analyses

c. Water Description.

(1) Keyword line

(a) Content (one line)

[LN] "WATR" WLL WLR GAMW [S] [UC]

(b) Description

"WATR" = keyword for water description

WLL = left-side water elevation, ft

WLR = right-side water elevation, ft

GAMW = unit weight of water, kcf

S = seepage option

= -1 for line-of-creep method (calculated along the shortest seepage path)

= 0 for hydrostatic pressures to be computed

= 1 for pressures to be entered by the user

UC = uplift force normal to the base of the structural wedge, kips

(c) Note

1. If a value for S is not entered, the line-of-creep method is used to compute seepage pressures. If the water pressures are hydrostatic, pressures are computed for hydrostatic conditions.

2. The water elevation may be higher on either side. WLL may be greater than WLR or vice versa.

3. If option S = 1 is selected, the pressures entered for a wedge will be applied only to the submerged length of the wedge. The water elevations are used to calculate the submerged length of each wedge. Therefore, it is important to input the correct water elevations when using this option.

(d) Restriction: If UC is to be entered, S must also be entered. If a value for UC is not entered, the uplift force on the structure is computed by the same method used for the wedges.

(2) Water pressures on wedges (entered only if S = 1)

(a) Data line 1--Pressures on left-side wedges

1. Content (2 to 10 values)

[LN] PRESTP(1) PRESBP(1)

[LN] PRESTP(2) PRESBP(2) ...

[LN] ... PRESTP(NULAY) PRESBP(NULAY)

2. Description

PRESTP = pressure at the top of a left-side wedge, ksf

PRESBP = pressure at the bottom of a left-side wedge, ksf

NULAY = number of left-side soil layers

3. Comment: List pressures for all the left-side wedges from the top (highest) elevation to the bottom (lowest) elevation of each wedge. Pressure is distributed linearly between the points entered. An example is shown in Figure 25.

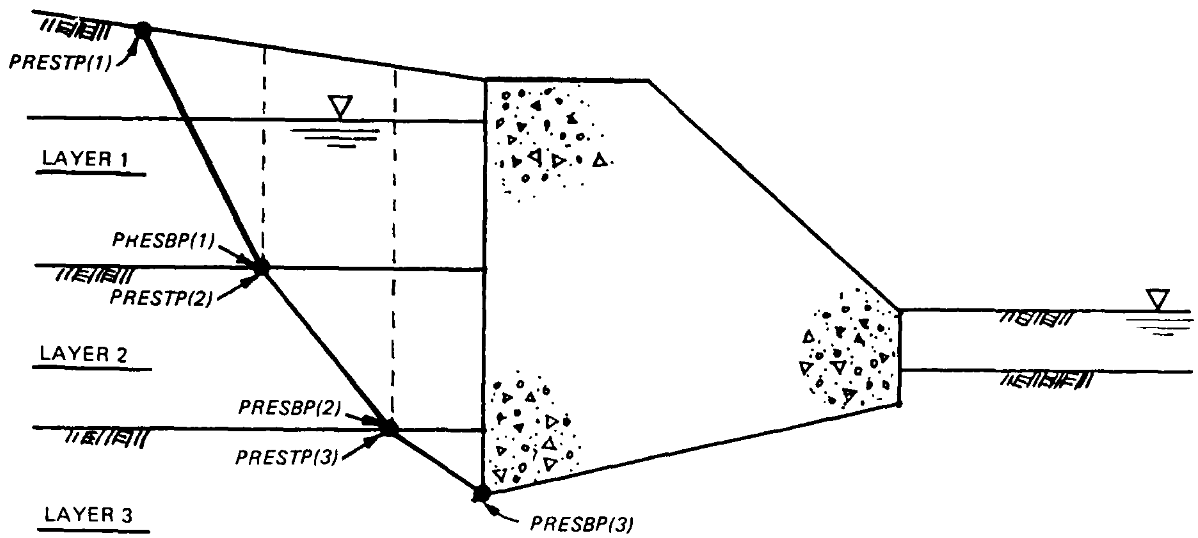


Figure 25. Input pressures on left-side wedges

(b) Data line 2--Number of pressure values on structural wedge (Do not enter this line if a value for UC was entered)

1. Content (one line)

   [LN] NPRST

2. Description

   NPRST = number of pressure values to be entered on the structural wedge

3. Note: NPRST must be between 2 and 5, inclusive.

(c) Data line 3--Pressures under structural wedge (not entered if a value for UC was entered)

1. Content (one line, maximum five points)

   [LN] XCOR(1) PRESC(1) XCOR(2) PRESC(2)
   [LN] XCOR(NPRST) PRESC(NPRST)

2. Description

   XCOR = X-coordinates along the structural base at which a pressure is to be entered, ft

   PRESC = pressure due to uplift on the structural base at "XCOR", ksf

3. Note: Pressure is distributed linearly between the points entered. The horizontal distance is always used to locate a pressure. The program automatically calculates the sloped distance between pressure values when the base of the structure is inclined to the horizontal. An example of how to enter the pressure values is shown in Figure 26.

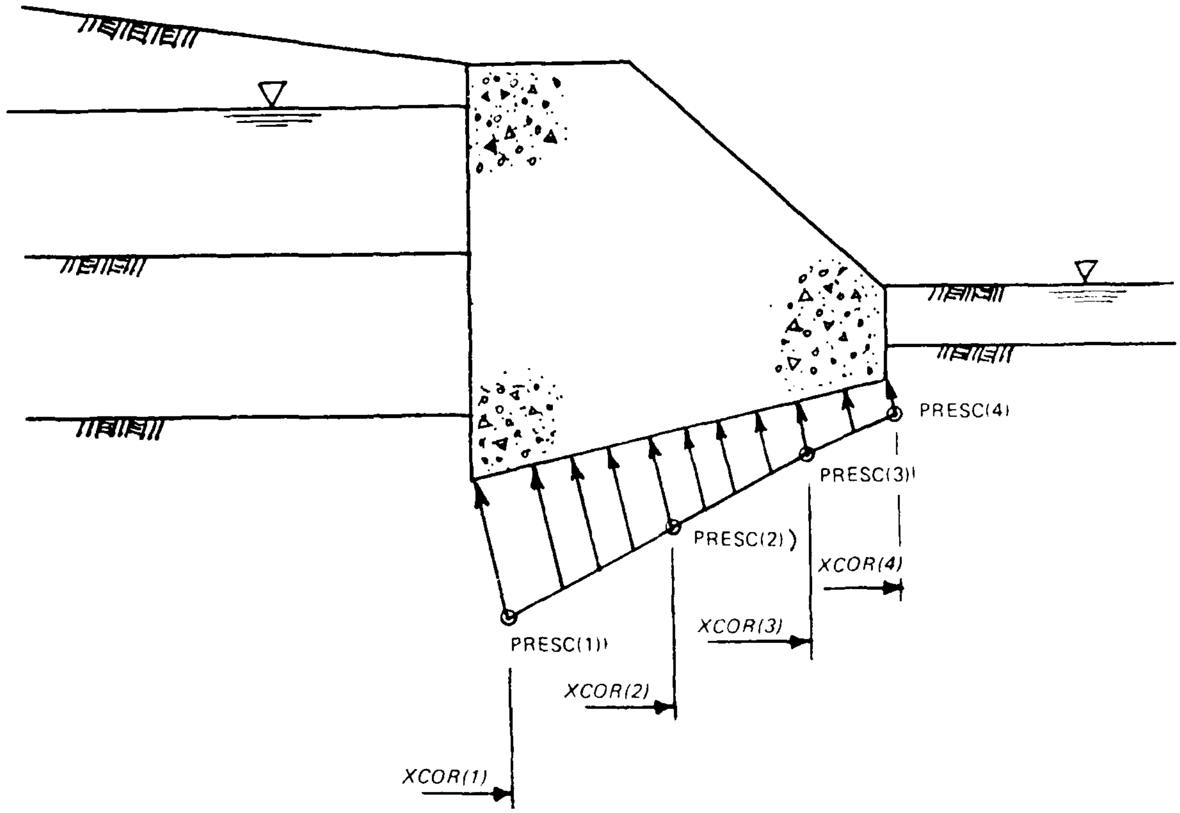


Figure 26. Input pressures on structural wedge

(d) Data line 4--Pressures under right-side wedge

1. Content (2 to 10 values)

   [LN] PRESTP(1) PRESBP(1)

   [LN] PRESTP(2) PRESBP(2)...

   [LN]...PRESTP(NDLAY) PRESBP(NDLAY)

2. Description

   PRESTP = pressure at the top of a right-side wedge, ksf

PRESBP = pressure at the bottom of right-side wedge, ksf

NDLAY = number of right-side layers

3. Comment: List pressures for all the right-side wedges from the top (highest) elevation to the bottom (lowest) elevation of each wedge. Pressure is distributed linearly between entered points. An example is shown in Figure 27.

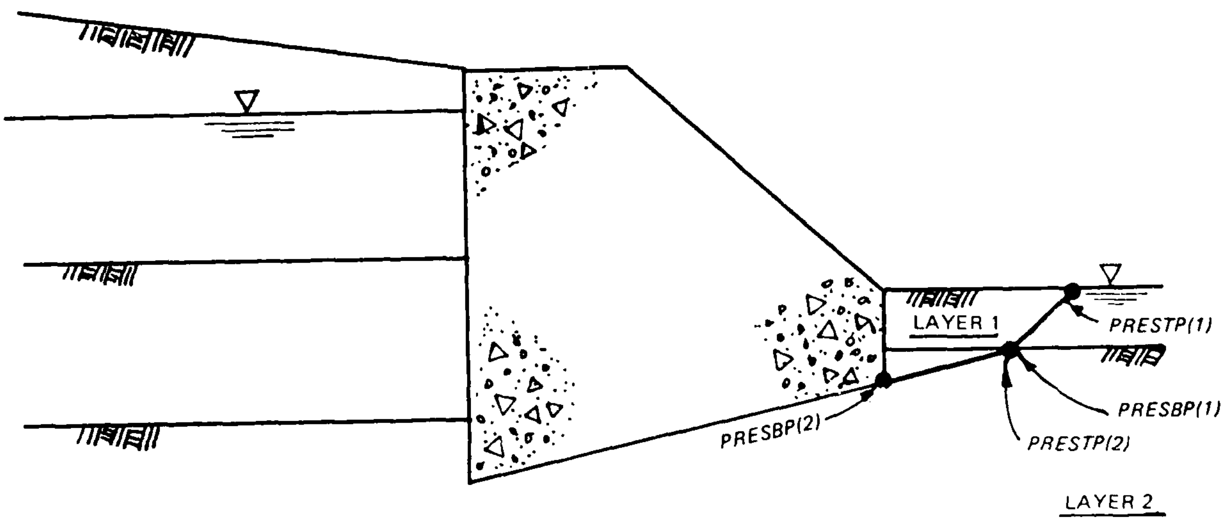


Figure 27. Input pressure on right-side wedges

d. Termination of Data Input.

(1) Content (one line)

[LN] "END"

(2) Description

"END" = keyword to end data entry

Optional data description

128. An explanation of the optional data sections is provided below.

a. Wedge Angle Specification.

(1) Content (one line per wedge angle specified)

[LN] "WEDG" IWEDGE FANG

(2) Description

"WEDG" = keyword for wedge angles to be specified

IWEDGE = number of the wedge to have an angle specified (Figure 28 shows the numbering sequence of the wedges)

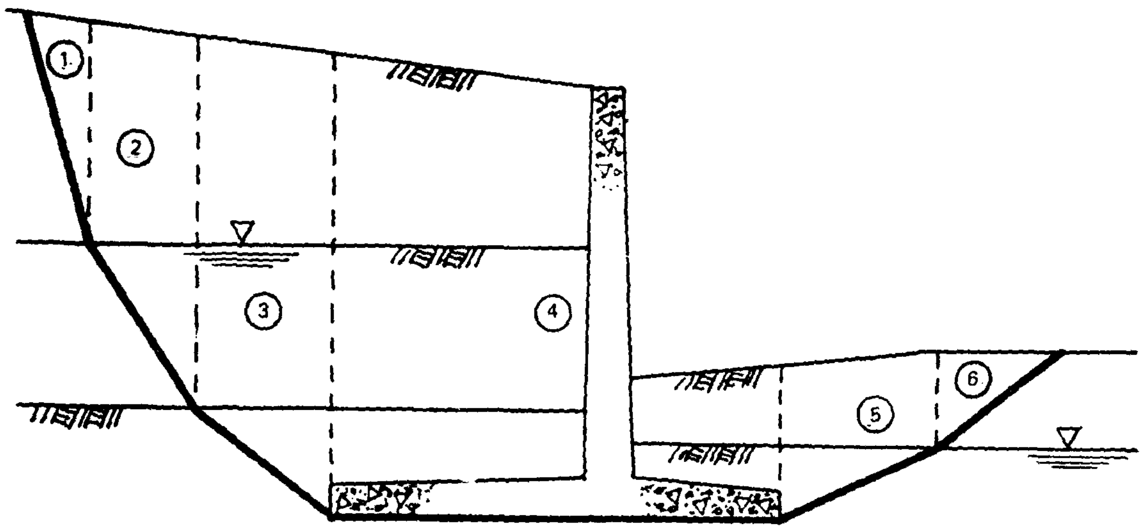


Figure 28. Numbering of wedges

FANG = failure angle (clockwise from horizontal is *negative; counterclockwise from horizontal is positive*)

(3) Restrictions

(a) Values of the input angle for left-side and right-side wedges may range from -85.0 to +85.0 deg, inclusive.

(b) The line defined by the rotation of the angle should not extend into the interior of the structure.

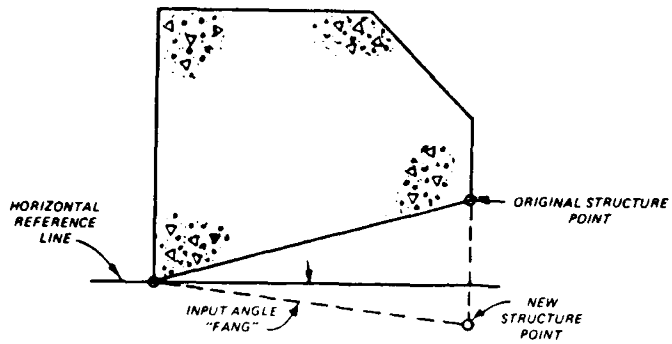
(c) If the single-plane analysis (Method 1, paragraph 87, Figure 17) is used for a multiple-layer problem, an angle set for any wedge (left or right) will cause all the angles on that side to be set to the input angle.

(d) An input wedge angle must allow the plane formed by the base of the wedge to intersect the soil layer in which the wedge is contained.

(4) Editing: To erase any input wedge angle, enter FANG = -999.

(5) Note

(a) The geometry of the structural wedge is altered when an angle is input for the structural wedge. The bottom corner point of the structural wedge opposite the input angle is moved down to a new elevation at the same X-coordinate. Figure 29 illustrates how the structural wedge geometry is altered as a result of an input angle. This point is the intersection of the line defined by the input angle with the



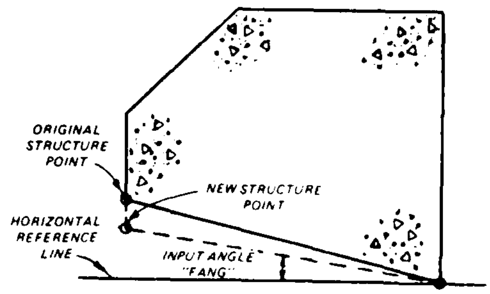


Figure 29. Structural wedge input angle

X-coordinate boundary of the structure as shown in Figure 29. The point of rotation for the input angle is always the corner of the structure with the lowest elevation. If the base of the structure is level, the input angle is rotated about the left corner of the structure.

(b) The plane defined by the input angle is the new plane of sliding. The soil beneath the structure is assumed to be an added vertical load.

(c) The weight of the soil below the structure is calculated using the unit weight of the lowest soil layer which is opposite the side of the structure on which the input angle is applied (see Figure 29).

b. Earthquake Conditions.

(1) Content (one line)

[LN] "EQAC" EQVT EQHO

(2) Description

"EQAC" = keyword for earthquake accelerations

EQVT = vertical acceleration coefficient

EQHO = horizontal acceleration coefficient

(3) Note: The horizontal seismic acceleration coefficient can be obtained from Table 1 of ER 1110-2-1806.* If included, the vertical acceleration coefficient can be taken as two thirds of the horizontal coefficient.

c. Factor of Safety Description.

(1) Content (one line)

[LN] "FACT" XLOW UPPER [FACTOR]

(2) Description

"FACT" = keyword for FS specifications

XLOW = lower limit of the FS

UPPER = upper limit of the FS

FACTOR = ratio of the passive FS to the active FS (DEFAULT = 1.0)

d. Vertical Surcharge Loads.

(1) Point/Line loads (maximum 10 loads)

(a) Content (one line per load)

[LN] "VPLO" XPLO PLO

(b) Description

"VPLO" = keyword for vertical line load

XPLO = X-coordinate of the load, ft

PLO = magnitude of the load, kips

(c) Note: If the load lies directly on the vertical boundary line which separates adjacent wedges, the load is included in the calculations of the wedge to the right. Figure 30 shows an example of a line load.

(2) Strip loads, Figure 31 (maximum 10 loads)

(a) Content (one line per load)

[LN] "VSLO" XL WS SMAG

(b) Description

"VSLO" = keyword for a strip load

XL = X-coordinate of the left end of the strip, ft

WS = width of the strip, ft

SMAG = magnitude of the load, k/ft

* Headquarters, Department of the Army. 1983 (May). "Earthquake Design and Analysis for Corps of Engineers Projects," ER 1110-2-1806, Washington, DC.

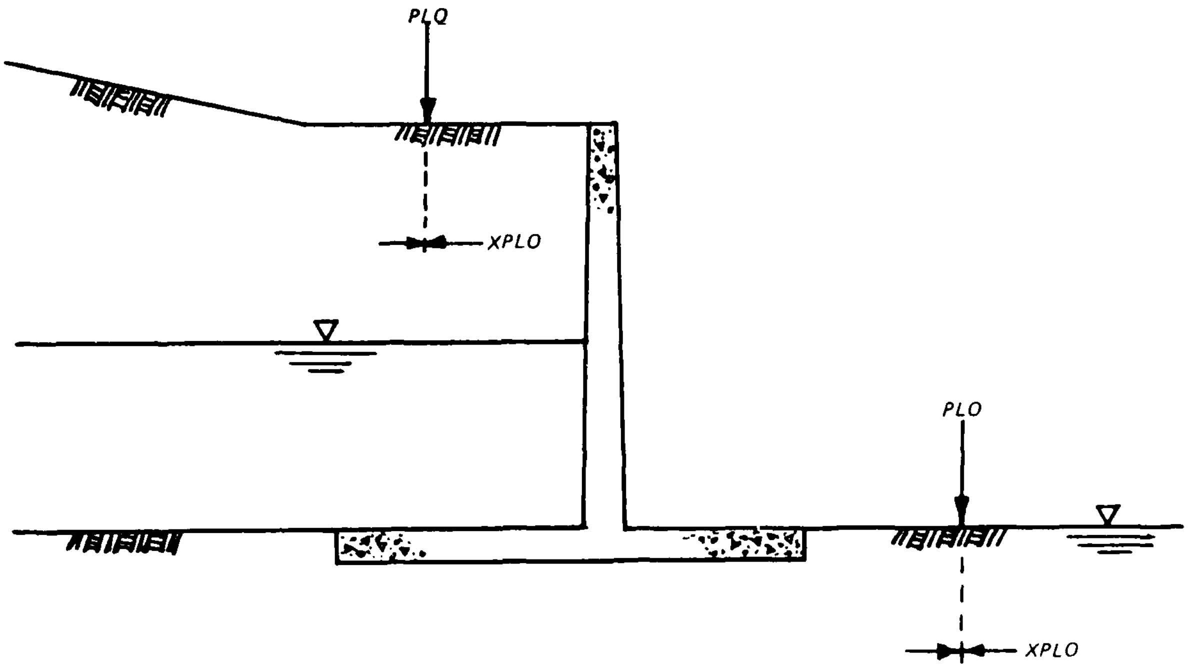


Figure 30. Point/line loads

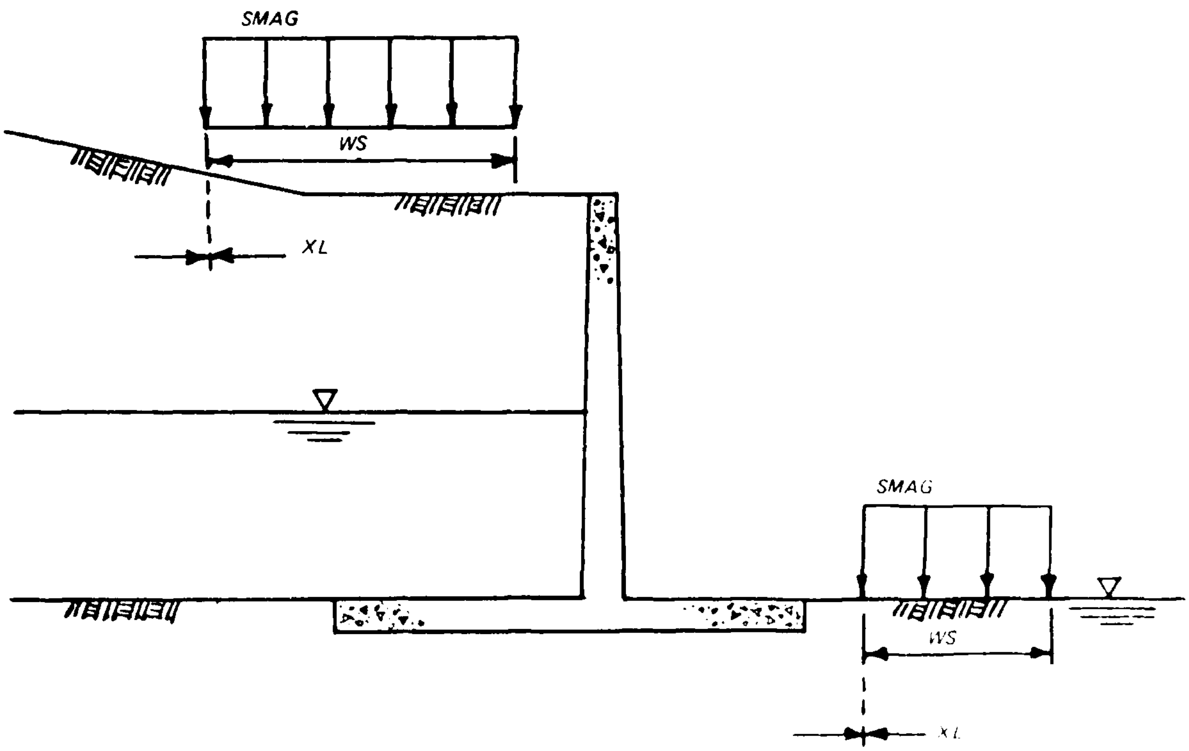


Figure 31. Strip loads

(3) Triangular loads, Figure 32 (maximum 10 loads)

(a) Content (one line per load)

[LN] "VTLO" XTL WTL WDL QMAX

(b) Description

"VTLO" = keyword for vertical triangular load

XTL = X-coordinate of the left end of the load, ft

WTL = width from left end to the maximum load, ft

WDL = width from maximum load to right end, ft

QMAX = maximum load, k/ft

(4) Ramp loads, Figure 33 (maximum 10 loads)

(a) Content (one line per load)

[LN] "VRLO" XRL WR QRAM

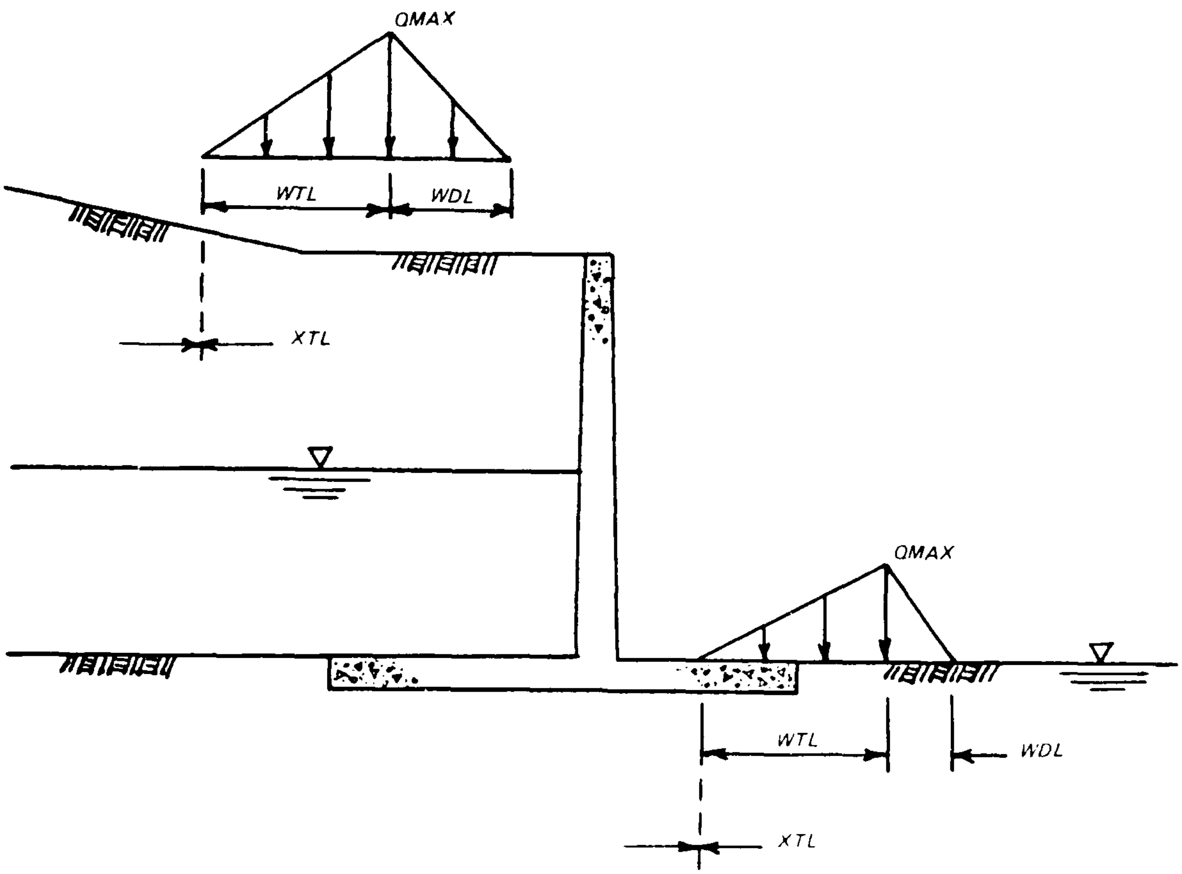


Figure 32. Triangular loads

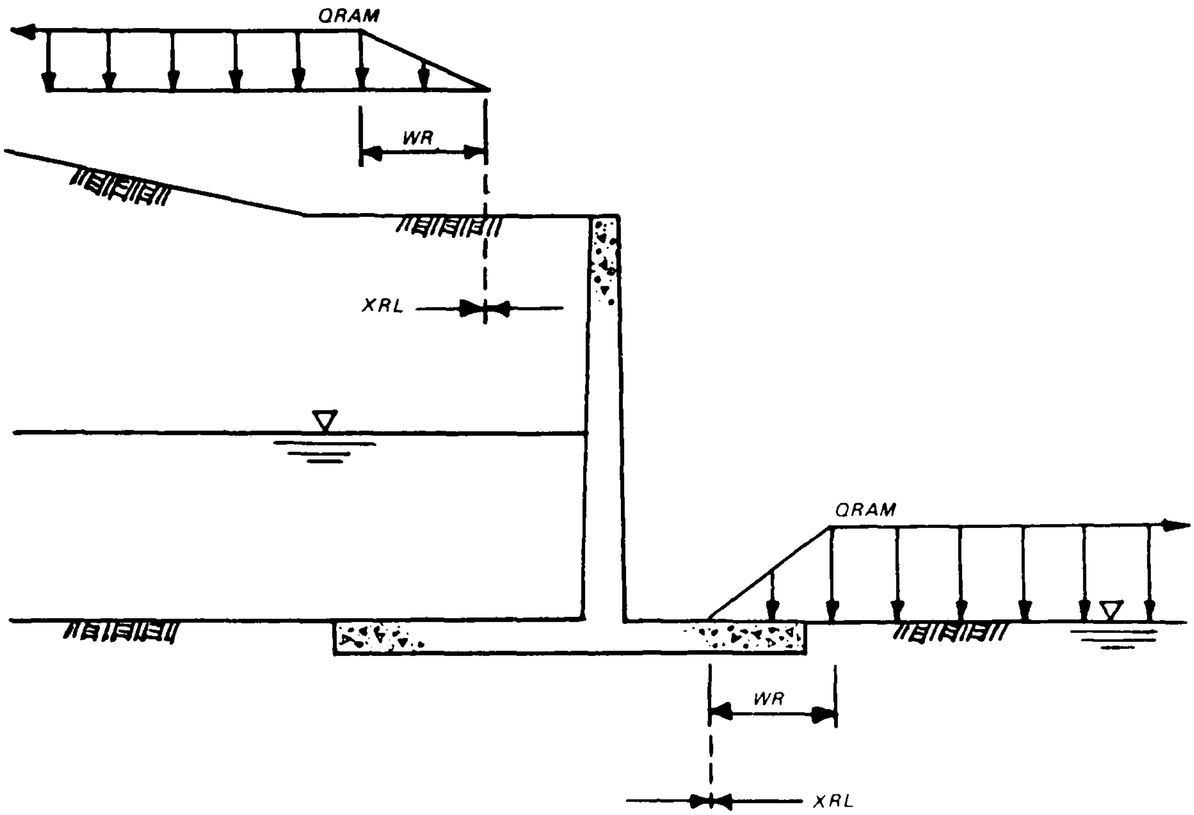


Figure 33. Ramp loads

(b) Description

"VRLO" = keyword for vertical ramp load

XRL = X-coordinate of the starting point of the ramp, ft

WR = width of the ramp (increasing load), ft

QRAM = maximum load, k/ft

(5) Uniform Loads (on either side of structure)

(a) Content (one line per side)

[LN] "VULO" SIDE QMAG

(b) Description

"VULO" = keyword for vertical uniform load

SIDE = "L" for left side of structure

= "R" for right side of structure

QMAG = magnitude of the load, k/ft

(c) Note: The uniform load extends over all the soil surface (L or R) and stops where the soil meets the concrete structure. An example of a uniform load is shown in Figure 34.

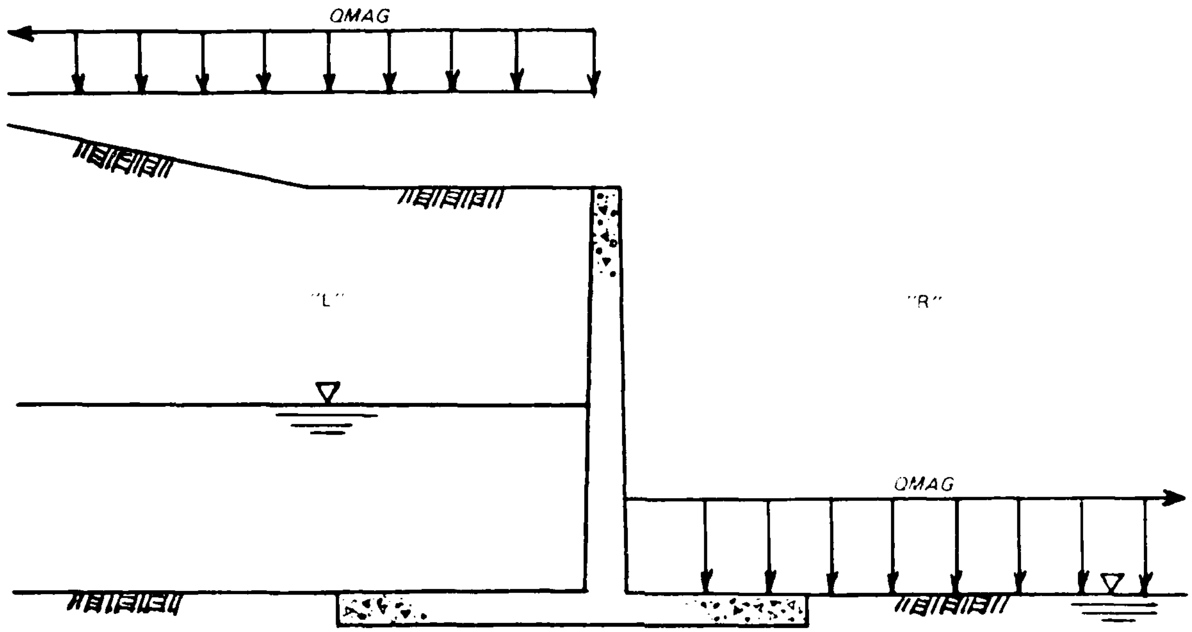


Figure 34. Uniform loads

(6) Delete all vertical loads

(a) Content (one line)

[LN] "NVLO"

(b) Description

"NVLO" = keyword command to cancel all vertical surcharge loads currently in the input data and to reinitialize all these values to zero

(7) Note: Each time the prompting sequence is used to enter or edit loads, all loading conditions are initialized to zero. Each time a keyword command is used to enter or edit a load, the load is added to those already existing. The exception to this is the vertical uniform load which retains only the last value entered for a particular side.

e. Horizontal Loads.

(1) Line load [illegible] wedge

(a) Content (one line per load)

[LN] [illegible]

(b) Description

"HOLO" = keyword for a horizontal load

WEDN = number of the wedge on which the load is applied (refer to Figure 28)

HLOAD = magnitude of the load

(c) Comment: The command may be repeated as often as necessary for each horizontal load on the same wedge and/or on different wedges (see Figure 35).

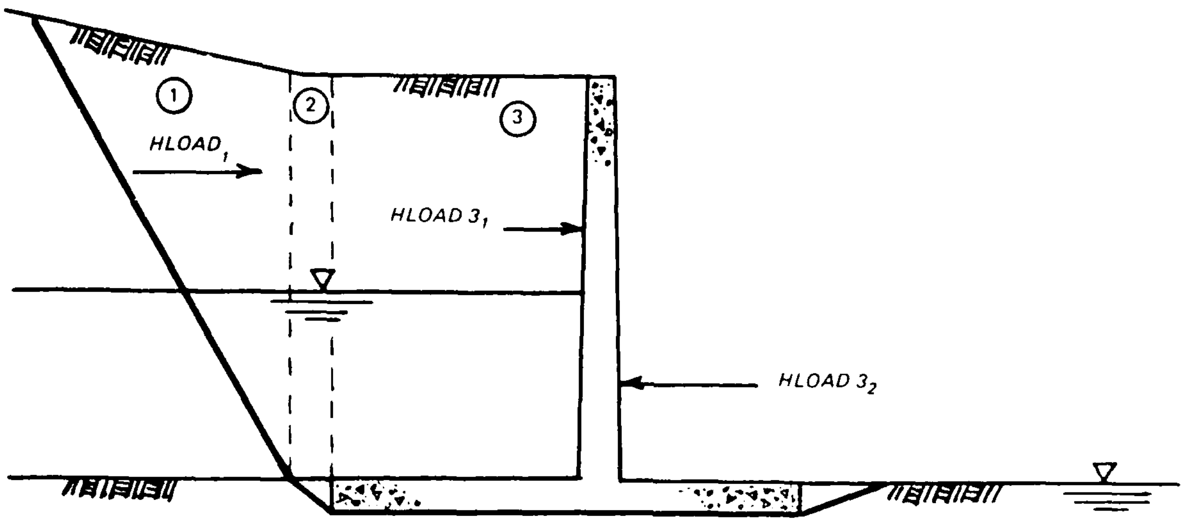


Figure 35. Horizontal loads

(2) Delete all horizontal loads

(a) Content (one line)

[LN] "NHLO"

(b) Description

"NHLO" = keyword command to cancel all horizontal loads on all the wedges that are part of the current input data (their values are reinitialized to zero)

(3) Note: Each time the prompting sequence is used to enter or edit loads, all loading conditions are initialized to zero. Each time a keyword command is used to enter or edit a load, the load is added to those existing.

[illegible]. Erase Title.

(1) Contents (one line)

[LN] NTIT

(2) Description

"NTIT" = keyword command [illegible] new one can be entered

g. Rerun Program with Altered Data from Within the File.

(1) Contents (one line)

[LN] "RERU"

(2) Description

"RERU" = keyword command allowing the user to modify the current data file and rerun the problem

(3) Restrictions

(a) This command can only be used in a data file following the "END" command of a set of data. It is not entered from the terminal.

(b) If "RERU" is used in a file, it must be followed by data in the file. Data to be modified is typed in the data file format described in paragraphs 119 and 131.

(c) "END" is a required keyword ending the list of data being modified.

h. New Problem Entered from Within a Data File.

(1) Contents (one line)

[LN] "NEW"

(2) Description

"NEW" = keyword command allowing the user to enter a new problem from a prepared data file (all current data is erased with this command)

(3) Restrictions

(a) This command can only be used in a data file. It follows the "END" command of a set of data. It is not entered from the terminal.

(b) If "NEW" is entered, data must follow it in the data file format described in paragraphs 119 and 132. All required data items listed in paragraph 121 must be entered.

Optional Methods and Examples of Data Entry

Data entry from the terminal using a prompting sequence

129. This option was introduced in paragraph 117. As previously stated, this method queries the user for information on all aspects of the problem, including required data as well as optional data. The following set of questions, shown as Figure [illegible], comprises the prompting sequence (user responses are underlined).

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? T

  DO YOU WANT TO USE A PROMPTING SEQUENCE?
  ENTER 'Y' OR 'N'.
? Y

 ENTER NUMBER OF HEADING LINES (1 TO 4)
? 1

 ENTER 1 HEADER LINES
 (1 TO 70 CHARACTERS PER LINE)


? LOCK & DAM #2
      STRUCTURE DESCRIPTION. ENTER THE FOLLOWING DATA

      NUMBER OF XY-COORD.         UNIT WEIGHT
      DEFINING STRUCTURE          OF CONCRETE
           (3 TO 20)                 (KCF)


?             9                      0.440

      ENTER  9 XY-COORD. TO DEFINE THE STRUCTURE
      (START WITH THE POINT AT THE LOWER LEFT-HAND
       CORNER, AND THEN CONTINUE CLOCKWISE.
       MAX OF 5 COORD PAIRS PER LINE  )


? -22.5 628.1 -22.5 692.6 -17.5 692.6 -17.5 712.8
? -9 712.8 0 694.1 18.5 694.1 22.5 667 22.5 628.1

 ENTER THE PERCENTAGE OF THE BASE OF THE STRUCTURE
 THAT IS IN COMPRESSION. (A DECIMAL NUMBER)

? 1.0

  DO YOU WANT TO ENTER ELEVATION OF THE
  INTERSECTION OF THE LEFT SIDE FAILURE
  ANGLE AT STRUCTURE ('Y' OR 'N')
? N

 LEFT SIDE SOIL DESCRIPTION.

 ENTER NUMBER OF SOIL LAYERS (1 TO 5)
? 2
```

Figure 36. Prompting sequence of program CSLIDE (Sheet 1 of 3)

ENTER SOIL LAYER DATA UNDER HEADING. (ONE LINE PER LAYER)

SOIL NUMBER	INTERNAL FRICTION ANGLE(DEG)	COHESION (KSF)	SATURATED UNIT WEIGHT (KCF)	ELEVATION AT STRUCTURE
? 1	30	0	0.125	669.1
? 2	27	0	0.110	630.8

ENTER NUMBER OF POINTS THAT DESCRIBE
LAYER 1
? 2

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? -500 660 -38 660

ENTER NUMBER OF POINTS THAT DESCRIBE
LAYER 2
? 1

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? -500 630.8

SOIL BELOW STRUCTURE
ENTER DATA UNDER HEADINGS.

	FRICTION ANGLE(DEG)	COHESION (KSF)
?	27	0

RIGHT SIDE SOIL DESCRIPTION.

ENTER NUMBER OF SOIL LAYERS (1 TO 5)
? 2

ENTER SOIL LAYER DATA UNDER HEADING. (ONE LINE PER LAYER)

SOIL NUMBER	INTERNAL FRICTION ANGLE(DEG)	COHESION (KSF)	SATURATED UNIT WEIGHT (KCF)	ELEVATION AT STRUCTURE
? 1	30	0	0.125	666.1
? 2	27	0	0.110	630.8

ENTER NUMBER OF POINTS THAT DESCRIBE
LAYER 1
? 5

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? 52.5 666.1 66 660 93 655 133 640 500 640

Figure 36. (Sheet 2 of 3)

```
 ENTER NUMBER OF POINTS THAT DESCRIBE
 LAYER 2
? 1

 ENTER COORDINATES DESCRIBING THE SOIL LAYER
 FROM LEFT TO RIGHT
? 500 630.8

WATER DATA. ENTER VALUES UNDER HEADING

LEFT SIDE  RIGHT  SIDE   UNIT        SEEPAGE OPTION
ELEVATION   ELEVATION   WEIGHT   -1 = LINE OF CREEP
  (FT)        (FT)      (KCF)     0 = HYDROSTATIC
                                  1 = INPUT PRESSURES

? 687.2         675          0.0625       -1

IS UPLIFT FORCE AT THE BASE OF THE STRUCTURE
TO BE SPECIFIED? (ENTER 'Y' OR 'N')
? Y

ENTER UPLIFT FORCE AT THE BASE OF THE
STRUCTURE (KIPS/FT)

? 667.5

ARE ANY WEDGE FAILURE ANGLES TO BE SPECIFIED?
(ENTER 'Y' OR 'N')
? N

 ARE ANY LOADS TO BE SPECIFIED?
 ENTER 'Y' OR 'N'
? N

ENTER METHOD OF ANALYSIS TO BE USED
  1 FOR SINGLE PLANE ANALYSIS
  2 FOR MULTI PLANE  ANALYSIS
? 2

DO YOU WANT TO ENTER INITIAL ESTIMATES OF THE FACTOR OF SAFETY?
(ENTER 'Y' OR 'N')
? N

DO YOU WANT TO ENTER THE RATIO OF THE
PASSIVE FACTOR OF SAFETY TO THE ACTIVE
FACTOR OF SAFETY, FSP/FSA?
ENTER 'Y' OR 'N'
? N

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
?
```

Figure 36. (Sheet 3 of 3)

Keyword data entry

130. This option was discussed in paragraph 118. An example of terminal input using command words is shown in Figure 37 (user responses are underlined).

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? T

  DO YOU WANT TO USE A PROMPTING SEQUENCE?
  ENTER 'Y' OR 'N'.
? N

 ENTER KEYWORD. TYPE 'END' TO EXIT, 'LIST'
 TO LIST KEYWORDS
? TITL LOCK & DAM #2

 NEXT?
? STRU 9 0.44

 ENTER XY COORD. TO DEFINE THE STRUCTURE
 (START AT LOWER LEFT-HAND CORNER AND
 PROCEED CLOCKWISE)
? -22.5 628.1  -22.5 692.6  -17.5 692.6  -17.5 712.8
? -9 712.8  0 694.1  18.5 694.1  22.5 667  22.5 628.1
```

Figure 37. Terminal input using command words (Continued)

```
NEXT?
? SOLT 1 2 30 0 0.125 669.1

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? -500 660 -38 660

NEXT?
? SOLT 2 1 27 0 0.11 630.8

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? -500 630.8

NEXT?
? SORT 1 5 30 0 0.125 666.1

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? 52.5 666.1  66 660  93 655  133 640  500 640

NEXT?
? SORT 2 1 27 0 0.11 630.8

ENTER COORDINATES DESCRIBING THE SOIL LAYER
FROM LEFT TO RIGHT
? 500 630.8

NEXT?
? SOST 27 0

NEXT?
? WATR 687.2 675 0.0625 -1 667.5

NEXT?
? METH 2

NEXT?
? END

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
?
```

Figure 37. (Concluded)

Data entry from a file

131. This option was discussed in paragraph 119. An example of a data file and an example of the sequence of questions to enter data from a file are shown in Figures 38 and 39.

```
00100 TITL LOCK & DAM #2  ("TITL" TITLE)
00110 SOLT 1 2 30 0 .125 669.1  ("SOLT" NLT LPTS PHIL COL)
00120 -500 660 -38 660  (XL(1) YL(1) XL(2) YL(2))
00130 SOLT 2 1 27 0 .11 630.8  ("SOLT" NLT LPTS PHIL COL CAML STELL)
00140 -500 630.8  (XL(1) YL(1))
00150 STRU 9 .44  ("STRU" IPT GAMC)
00160 -22.5 628.1 -22.5 692.6 -17.5 692.6  (XC(1) YC(1) XC(2) YC(2))
00170 -17.5 712.8 -9 712.8 0 694.1  (XC(4) YC(4)...XC(6) YC(6)) (XC(3) YC(3))
00180 18.5 694.1 22.5 667 22.5 628.1  (XC(7) YC(7)...XC(9) YC(9))
00190 SOST 27 0  ("SOST" PHIC CCS)
00200 SORT 1 5 30 0 .125 666.1  ("SORT" NRT RPTS PHIR COR GAMR STELR)
00210 52.5 666.1 66 660 93 655 133 640 500 640  (XR(1) YR(1)...XR(5) YR(5))
00220 SORT 2 1 27 0 .11 630.8  ("SORT" NRT RPTS PHIR COR GAMR STELR)
00230 500 630.8  (XR(1) YR(1))
00240 METH 2  ("METH" MEAN)
00250 WATR 687.2 675 .0625 -1 667.5  ("WATR" WLL WLR GAMW (S) (UC)
00350 END  ("END")
/
```

Figure 38. Example of a data file

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? F

 ENTER DATA FILE NAME (MAXIMUM 7 CHARACTERS)
? LD2

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
?
```

Figure 39. Example of how to enter a data file

Editing Input Data

132. All input data entered from the terminal or from a file may be edited by the user before and after the solution of the problem. Data is edited by sections of input (paragraph 120); therefore all information associated with a section must be reentered, even if some data items are not to be changed. The variables of all the other sections retain the input values last entered. If an optional data item has been entered, its value is also retained until the user cancels or changes the value.

133. Prior to solution, data may be changed as often as desired until the user is satisfied with the input. The last values entered are the ones used in the solution.

134. There are two methods for editing the input data from the terminal. These correspond to the two methods of data entry from the terminal (prompting sequence and command words, paragraphs 117 and 118).

135. Input data may also be edited from within a data file. This method is the same as entering data from a data file as described in paragraph 119.

Keyword commands method

136. To use this method, the user types the keyword for the section to be changed along with all associated data. The lines are typed in the format shown in the "Input Description" (paragraph 125). Line numbers are not used when editing during program execution.

137. The keyword commands method is quicker and more flexible than the prompting sequence and is recommended for the more experienced user. An example is shown in Figure 40.

```
INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? Y

 DO YOU WANT TO EDIT USING KEYWORDS
 OR SECTIONS ? (ENTER 'K' OR 'S')
? K

 ENTER KEYWORD. TYPE 'END' TO EXIT, 'LIST'
 TO LIST KEYWORDS
? VPLO -20.4 55.6

 NEXT?
? VPLO -10.4 226.8

 NEXT?
? WEDG 1 -65

 NEXT?
? WEDG 2 -65

 NEXT?
? WEDG 4 17.2

 NEXT?
? WEDG 5 17.2

 NEXT?
? HOLO 3 6.05

 NEXT?
? END

 DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
 TERMINAL, FILE, BOTH, OR NEITHER?
 ENTER 'T', 'F', 'B' OR 'N'
?
```

Figure 40. Example of keyword commands method for editing input data

Editing by sections

138. Editing by sections requires the user to answer questions about the section being edited. This method is generally more time consuming than editing by keywords and is recommended for the inexperienced user. An example is shown in Figure 41.

```
INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? Y

 DO YOU WANT TO EDIT USING KEYWORDS
 OR SECTIONS ? (ENTER 'K' OR 'S')
? S

 INPUT IS DIVIDED INTO THE FOLLOWING SECTIONS:

 SECTION ID        SECTION CONTENTS

     A             HEADING
     B             STRUCTURE DESCRIPTION
     C             LEFT SIDE SOIL DESCRIPTION
     D             SOIL BELOW STRUCTURE
     E             RIGHT SIDE SOIL DESCRIPTION
     F             WATER DESCRIPTION
     G             WEDGE ANGLES SPECIFIED
     H             SURCHARGE AND HORIZONTAL LOADS
     I             TYPE OF ANALYSIS AND SAFETY FACTOR

 ENTER SECTION ID FOR DATA TO BE CHANGED.
? H

  ARE ANY LOADS TO BE SPECIFIED?
  ENTER 'Y' OR 'N'
? Y

  ENTER A NEGATIVE NO. TO KEEP EXISTING DATA.
  ENTER A ZERO (0) TO DELETE A LOAD.
  POSITIVE VERTICAL LOADS ARE ASSUMED TO ACT
  DOWNWARD.  POSITIVE HORIZONTAL LOADS ARE
  ASSUMED TO ACT TO THE RIGHT.

  ENTER NUMBER OF VERTICAL POINT LOADS
? 2
 ENTER X-COORD AND MAGNITUDE OF LOAD
? -20.4 55.6
```

Figure 41. Example of editing by sections (Continued)

```
 ENTER X-COORD AND MAGNITUDE OF LOAD
? -10.4 226.8

 ENTER NUMBER OF STRIP LOADS
? 0

 ENTER NO. OF TRIANGULAR LOADS
? 0

 ENTER NUMBER OF RAMP LOADS
? 0

 UNIFORM LOAD LEFT SIDE
? 0

 UNIFORM LOAD RIGHT SIDE
? 0

 ENTER NUMBER OF HORIZONTAL LOADS
? 1

 ENTER:   WEDGE NUMBER    LOAD
?                3         6.05

 ENTER VERTICAL AND HORIZONTAL SEISMIC
 ACCELERATIONS (G)
? 0 0
 ENTER NEXT SECTION ID FOR DATA TO BE CHANGED
 (TYPE 'LIST' FOR A LIST OF SECTIONS)
 (TYPE 'END' WHEN EDITING IS COMPLETED)
? G

 ARE ANY WEDGE FAILURE ANGLES TO BE SPECIFIED?
 (ENTER 'Y' OR 'N')
? Y

 WEDGES ARE NUMBERED STARTING FROM THE LEFT TO RIGHT
 FOR THIS PROBLEM, THE FIRST 2 WEDGES ARE LEFT OF
 THE STRUCTURE, THE 3TH IS BELOW THE STRUCTURE, AND
 THE LAST 2 ARE RIGHT OF THE STRUCTURE

 ENTER THE NUMBER OF WEDGES THAT ARE TO HAVE
 FAILURE ANGLES SPECIFIED.
? 4

 ENTER 4 LINES OF DATA UNDER HEADING.
  WEDGE         FAILURE ANGLE
  NUMBER      COUNTER-CLOCKWISE
              IS POSITIVE (DEG)
? 1              -65
? 2              -65
? 4              17.2
? 5              17.2

 ENTER NEXT SECTION ID FOR DATA TO BE CHANGED
 (TYPE 'LIST' FOR A LIST OF SECTIONS)
 (TYPE 'END' WHEN EDITING IS COMPLETED)
? END
```

Figure 41. (Concluded)

Editing inside a data file

139. Another method of editing data is available only when a data file is used as the method of entering data into the program. The editing is set up within the prepared data file, prior to entering the file into the program.

140. Two optional keyword commands comprise this method of editing. They are "RERU" and "NEW". The "RERU" command allows the user to alter data of the previous run, and rerun the problem for analysis. The "NEW" command erases all of the previously entered data and allows a new set of data to be entered. These commands can be repeated and/or combined as often as the user desires. Each is followed by keyword lines and data lines as in a data file.

141. These commands are described in detail in paragraphs 128 g and h. An example of their use follows in Figure 42.

1st problem

```
00100 TITL LOCK & DAM #2
00110 SOLT 1 2 30 0 .125 669.1
00120 -500 660 -38 660
00130 SOLT 2 1 27 0 .11 630.8
00140 -500 630.8
00150 STRU 9 .44
00160 -22.5 628.1 -22.5 692.6 -17.5 692.6
00170 -17.5 712.8 -9 712.8 0 694.1
00180 18.5 694.1 22.5 667 22.5 628.1
00190 SOST 27 0
00200 SORT 1 5 30 0 .125 666.1
00210 52.5 666.1 66 660 93 655 133 640 500 640
00220 SORT 2 1 27 0 .11 630.8
00230 500 630.8
00240 METH 2
00250 WATR 687.2 675 0.0625 -1 667.5
00350 END
```

Edited run of 1st problem

```
00360 RERU
00370 WEDG 1 -65
00380 WEDG 2 -65
00390 WEDG 4  17.2
00400 WEDG 5  17.2
00410 VPLO -20.4 55.6
00420 VPLO -10.4 226.8
00430 HOLO 3 6.05
00440 END
```

Completely new problem

```
00450 NEW
00460 TITL UPST. DAM NO.4A
00470 STRU 9 .15
00480 0 0  0 5  10 12  10 35 15 35
00490 15 30.2 35.5 5  45 5  45 0
00500 SOLT 1 1 30 0 .115 15
00510 -100 15
00520 SOLT 2 1 32 0 .125 5
00530 -100 5
00540 SOST 34 0.04
00550 SORT 1 1 34 0.04 .126 5
00560 150 5
00570 WATR 32 15 .0625
00580 METH 2
00590 END
/
```

Figure 42. Example of use of "RERU" and "NEW" commands

Output Options

Echoprint of input data

142. After data have been entered into the program and after data have been edited, the user is given the option to have the current set of input data printed at the terminal, to a file, or to both the terminal and a file. The echoprint is a repeat of the information entered by the user in the format shown in Figure 43.

```
 -------------------------------
   PROGRAM CSLIDE - ECHOPRINT
 -------------------------------

 DATE:  86/06/25.                              TIME:  14.40.57.

 LOCK & DAM #2

 MULTI  FAILURE PLANE ANALYSIS

 SEEPAGE FORCE BY LINE OF CREEP, GRADIENT
 COMPUTED USING SHORTEST SEEPAGE PATH .

 NO OF CORNERS IN STRUCTURE ----------        9
 DENSITY OF CONCRETE -----------------     .4400(KCF)
 DENSITY OF WATER --------------------     .0624(KCF)
 WATER LEVEL LEFT SIDE ---------------   687.20(FT)
 WATER LEVEL RIGHT SIDE --------------   675.00(FT)
 NO. OF SOIL LAYERS LEFT SIDE --------        2
 NO. OF SOIL LAYERS RIGHT SIDE -------        2

 UPLIFT FORCE AT BASE OF STRUCTURE ---   667.500 (KIPS)


 STRUCTURE INFORMATION
```

Figure 43. Echoprint of current set of input data (Sheet 1 of 4)

POINT	X-COORD	Y-COORD
1	-22.50	628.10
2	-22.50	692.60
3	-17.50	692.60
4	-17.50	712.80
5	-9.00	712.80
6	.00	694.10
7	18.50	694.10
8	22.50	667.00
9	22.50	628.10

LEFTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.125	669.10
2	27.00	.0000	.110	630.80

LAYER	POINT NO. 1		POINT NO. 2	
NO	X-COORD	Y-COORD	X-COORD	Y-COORD
1	-500.00	660.00	-38.00	660.00
2	-500.00	630.80	********	********

Figure 43. (Sheet 2 of 4)

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 27.00
COHESION --------------- .0000

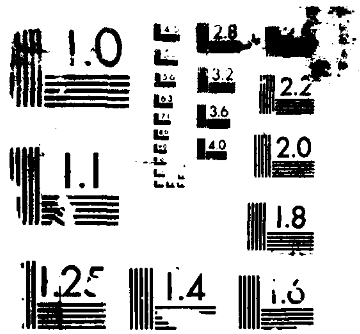
RIGHTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.125	666.10
2	27.00	.0000	.110	630.80

LAYER NO	POINT NO. 1 X-COORD	POINT NO. 1 Y-COORD	POINT NO. 2 X-COORD	POINT NO. 2 Y-COORD	POINT NO. 3 X-COORD	POINT NO. 3 Y-COORD
1	52.50	666.10	66.00	660.00	93.00	655.00
2	500.00	630.80	********	********	********	********

LAYER NO	POINT NO. 4 X-COORD	POINT NO. 4 Y-COORD	POINT NO. 5 X-COORD	POINT NO. 5 Y-COORD
1	133.00	640.00	500.00	640.00
2	********	********	********	********

AD-A189 334 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT 2/4
SLIDING STABILITY OF..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS INFOR..
UNCLASSIFIED M E PACE ET AL. OCT 87 WES/TR/ITL-87-5 F/G 12/5 NL


1.0
2.8
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

```
WEDGE NO.    ANGLE
---------    -----

    1        -65.00
    2        -65.00
    4         17.20
    5         17.20

VERTICAL POINT LOADS
--------------------

X-COORDINATE       MAGNITUDE
    (FT)             (KIPS)
------------       ---------

   -20.40            55.600
   -10.40           226.800

HORIZONTAL LOADS
----------------

 WEDGE NO    LOAD
 --------  -------

         3     6.050

DO YOU WANT TO PLOT THE INPUT DATA.  ENTER 'Y' OR 'N'.
?
```

Figure 43. (Sheet 4 of 4)

Edit and rerun option

143. After the solution is complete, the user is given the chance to edit the current data and rerun the problem. The data may be edited as discussed in paragraphs 132 through 141.

Iterations of the solution

144. Before the computations for the solution are printed, the user is given the option to print all the iterations of the solution.

Plotting option

145. The user is given the opportunity to have the input data plotted at the terminal before entering the solution part of the program.

146. After the solution is complete, the user is given the opportunity to have the final results plotted at the terminal. Final results plotted include the failure surface, each individual wedge with all loads shown, and the convergence of the solution. The plotting options are discussed in more detail in the following paragraphs.

Input and Output Graphics

Input graphics

147. After data have been entered for a problem, the user is given the opportunity to plot the input data. The question is asked:

```
DO YOU WANT TO PLOT THE INPUT DATA? ENTER 'Y' OR 'N'.
```

If the user selects to plot the input data, the screen is erased and a list of options are printed. The options available are:

```
B--Plot biggest possible picture of the current
   window. The plot is not drawn to scale.

A--Provide an axis for any subsequent plots.
   This command acts like a toggle switch;
   enter 'A' once to provide an axis, and
   enter 'A' again to delete the axis.

O--Provide an outline for the current plotting
   area. This command acts like a toggle switch.

I--Read in the boundaries of a desired window.
   The window is drawn to scale.

P--Pick a desired window using the cross hairs.
   The window is drawn to scale.

G--Provide a grid if the axis option is selected.
```

R--Replot the current picture.

T--Plot the total picture. This plot is drawn to scale.

S--Draw only the soil layers, structure, water elevations, and vertical and horizontal loads.

C--Continue. Exit the graphics and continue with the solution.

H--Help. Provide an explanation of each option.

Q--Quit. Terminate program execution.

148. Crosshairs will appear on the screen and the user may select any option by entering the letter associated with the option. Examples of the input graphics are shown in Figures 44 and 45.

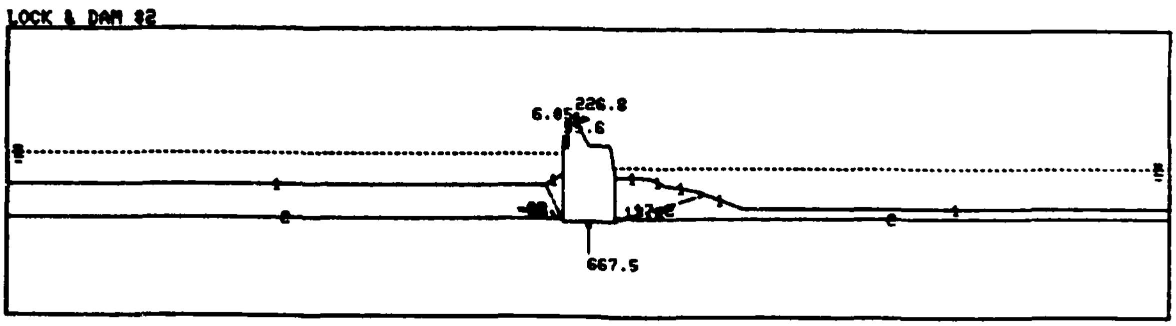


Figure 44. *Total plot*

Output graphics

149. After the solution is complete, the user is given the opportunity to plot the results of the analysis. The question is asked:

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.

If the user selects to plot the results, the screen is erased and a menu will be drawn as shown in Figure 46.

150. The user may select an option from the menu by placing the crosshairs inside the box containing the described option and entering any character.

151. The user has the option to plot the failure surface, the individual wedges, the convergence of the solution, or to continue with the program run. If the user selects to plot the failure surface, the screen will be erased and a list of options will be printed. Most of the options previously mentioned in paragraph 147 for plotting the input data are available. The option 'C' will return the user to the results menu. There is an additional

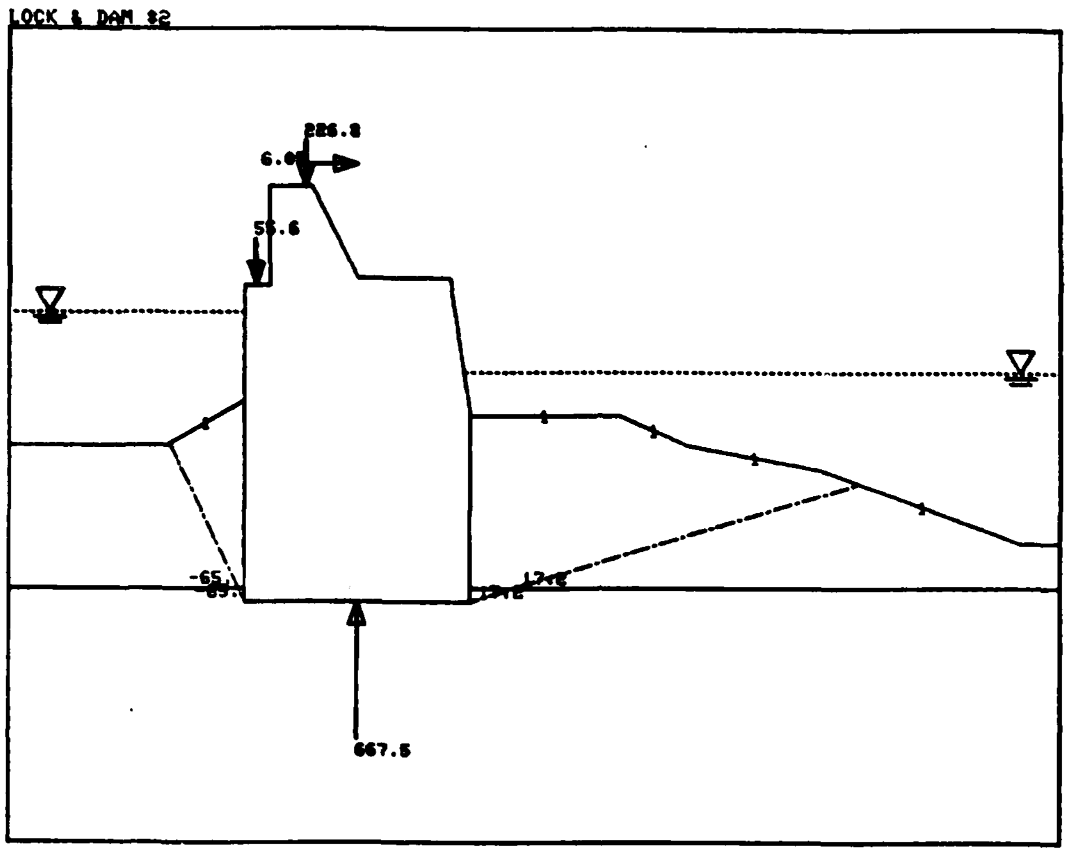


Figure 45. Window of plot

SELECT AN OPTION BY PLACING THE CROSSHAIRS IN THE BOX WITH THE DESIRED OPTION AND ENTER ANY CHARACTER

PLOT FAILURE SURFACE	PLOT WEDGES	PLOT CONVERGENCE	CONTINUE	HELP

Figure 46. Results menu

option, 'W', which plots the water pressures on the failure surface.

152. Crosshairs will appear on the screen and an option may be selected by entering the letter associated with the option. An example of the failure surface plot is shown in Figure 47.

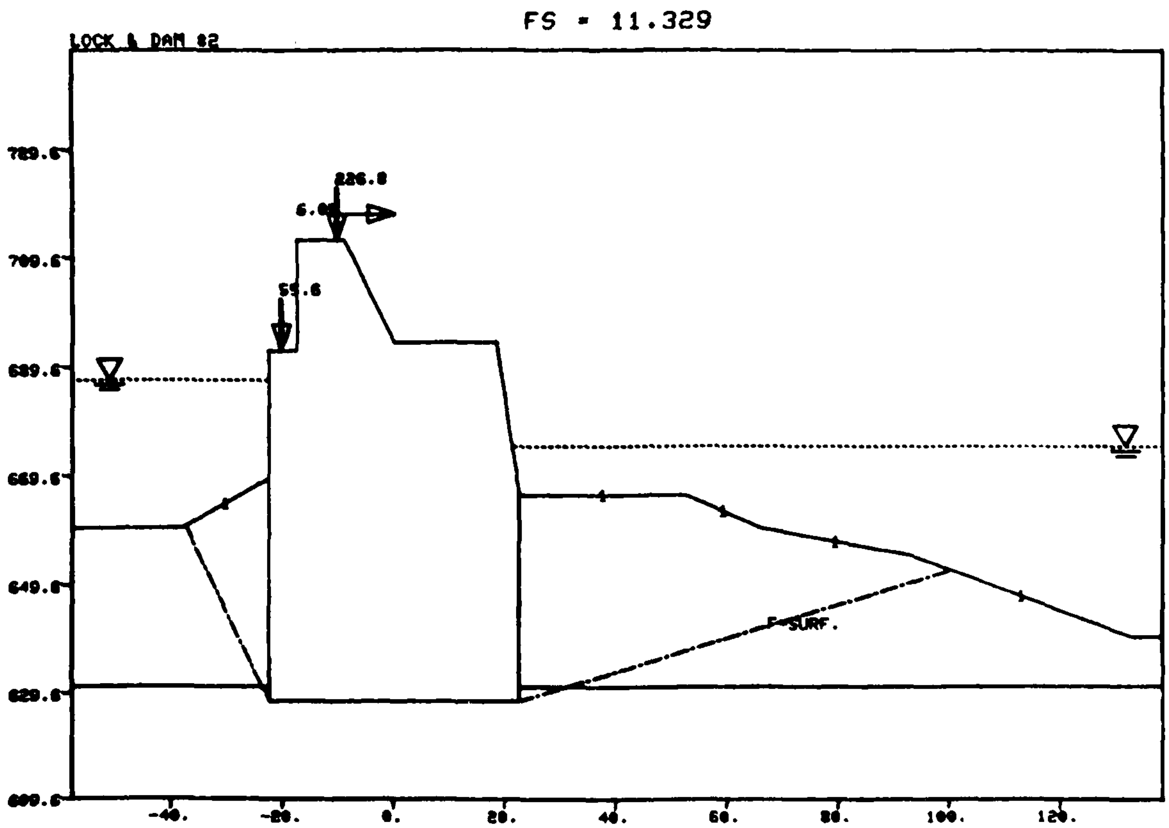


Figure 47. Failure surface plot

153. If the user selects to plot the convergence of the solution, the screen will be erased and a list of options will be printed. The following options are available:

B--Draw both convergence diagrams on one page.

F--Plot summation of net forces versus safety factor.

I--Plot summation of net forces versus iteration number.

C--Continue. Return to previous menu.

Q--Quit. Terminate program execution.

H--Help. Provide an explanation of each option.

154. Crosshairs will appear on the screen and an option may be selected by entering the letter associated with the option. An example of the convergence plot is shown in Figure 48.

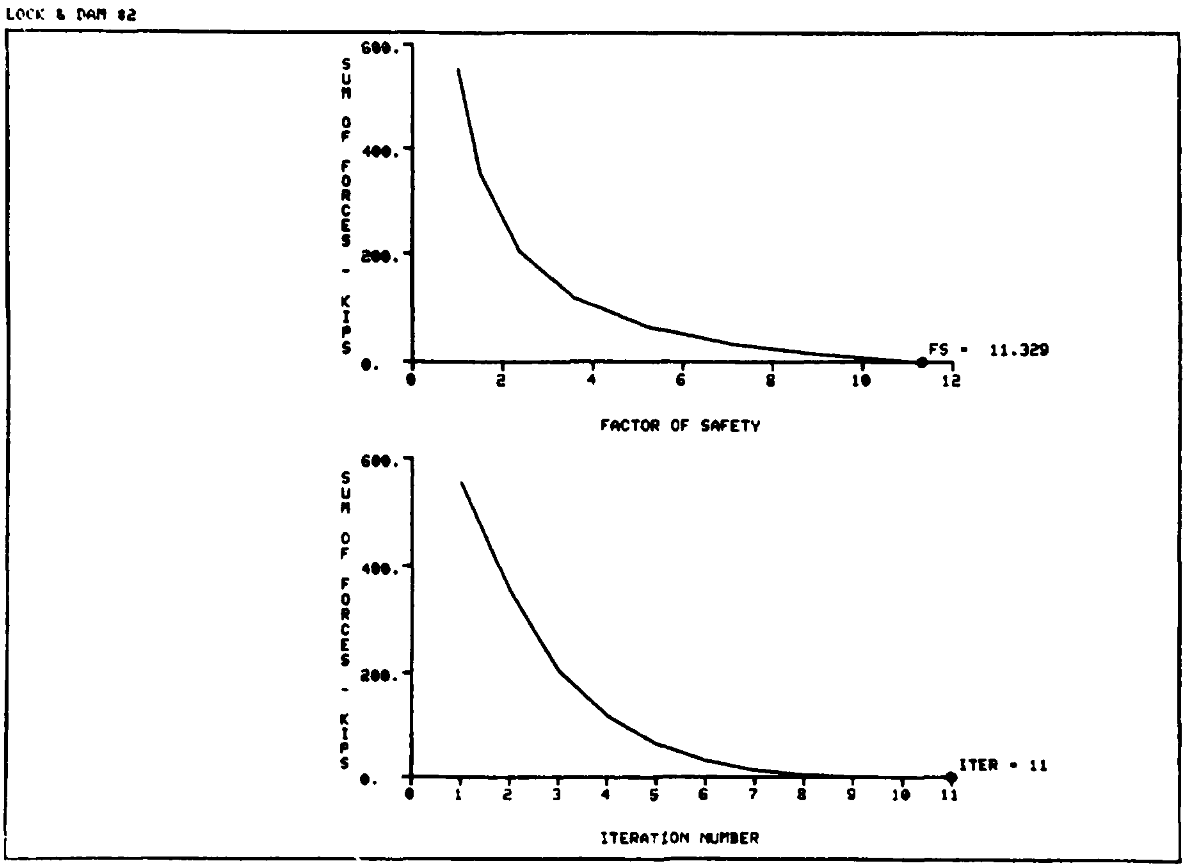


Figure 48. Convergence plot

155. If the user selects to plot the wedges, the screen will be erased and another menu shown in Figure 49 will be drawn.

156. The user has the option to plot any individual wedge, plot all of the wedges, return to the output menu, or continue with the program run.

157. If the user selects to draw an individual wedge, the screen will be erased and a list of options will be printed. Most of the options previously mentioned in paragraph 147 for plotting the input data are available. The options 'S' and 'O' do not apply, and the option 'C' will return the user to the wedge menu.

158. Crosshairs will appear on the screen and an option may be selected by entering the letter associated with the option.

159. If the user selects to plot all of the wedges, the screen will be erased and the first wedge will be drawn.

160. The crosshairs will appear after the wedge is drawn. Any of the options mentioned previously for plotting an individual wedge may be selected.

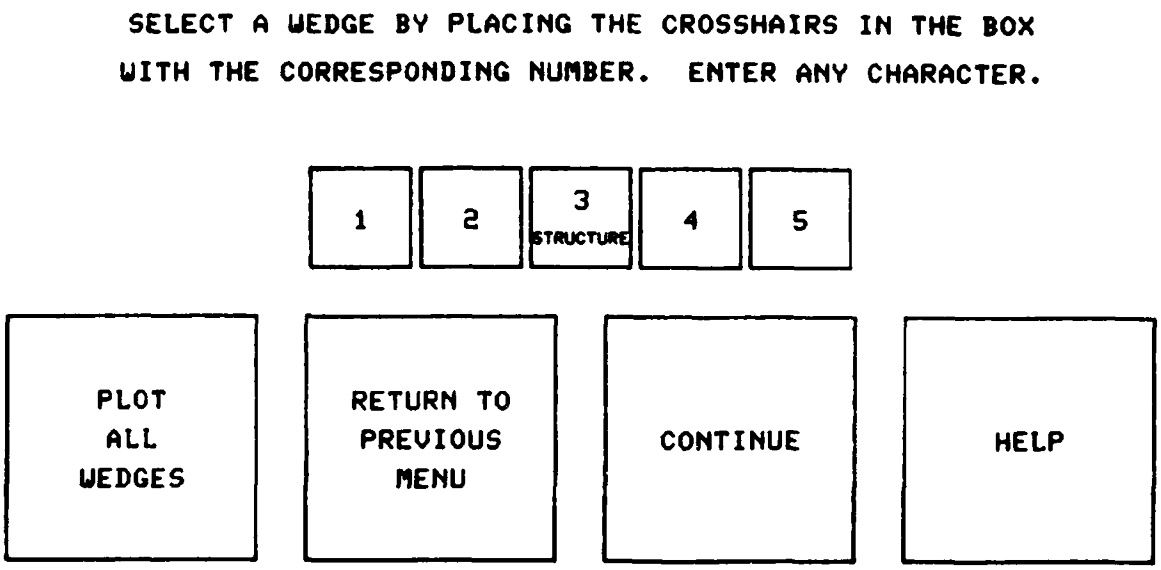


Figure 49. Wedge menu

When the option 'C' is chosen, the next wedge will be drawn. After the last wedge is drawn the wedge menu will be redrawn. An example of a wedge plot is shown in Figure 50.

Output

161. Results of the solution may be printed at the terminal, sent to a file, or both. The output file may be created at the terminal during execution.

162. The output format is shown in Figure 51. Optional features or special conditions for the particular problem appear as necessary.

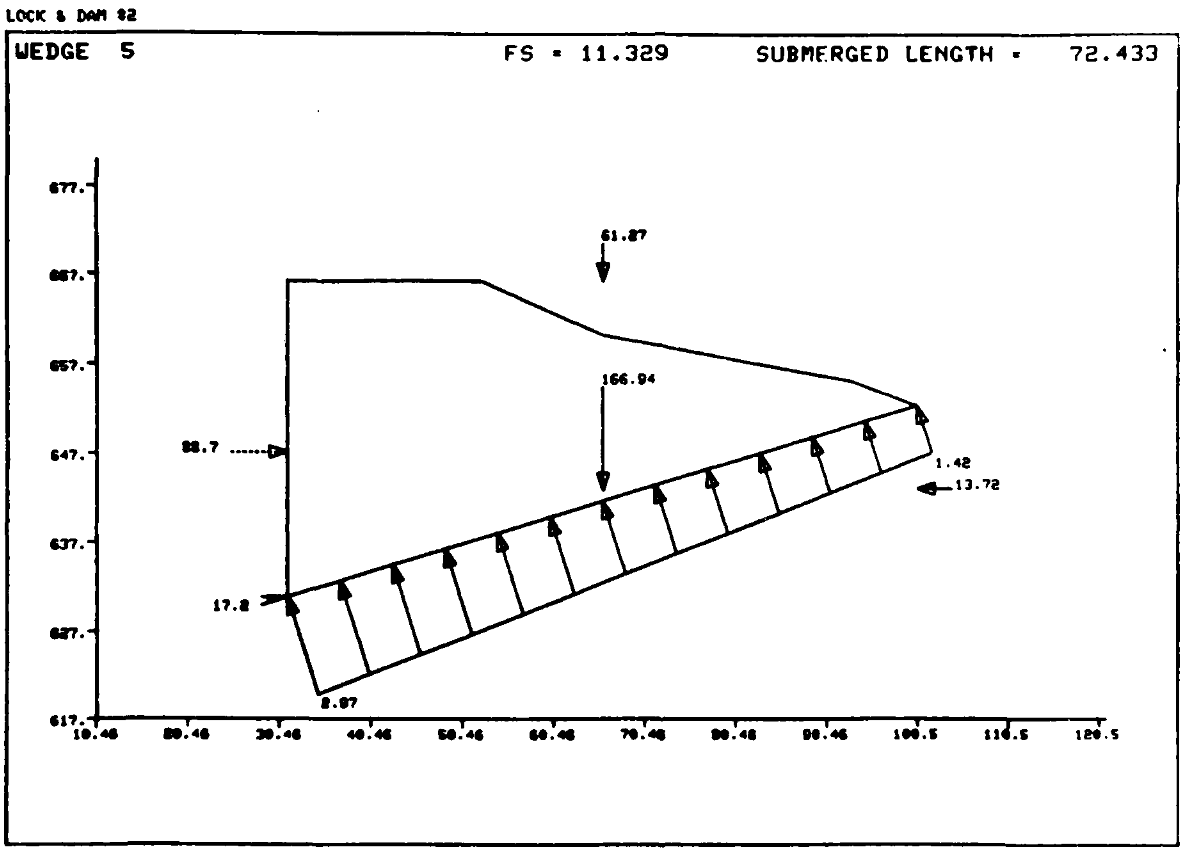


Figure 50. Wedge plot

```
-----------------------------------
  PROGRAM CSLIDE - FINAL RESULTS
-----------------------------------

DATE:  86/06/25.                                 TIME:  14.49.20.

LOCK & DAM #2


MULTIPLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP


                   HORIZONTAL LOADS
                   ----------------         VERTICAL
    WEDGE       LEFT   SIDE     RIGHT SIDE       LOAD
    NUMBER       (KIPS)          (KIPS)         (KIPS)
-------------------------------------------------------


      1         11.524           .000          19.628
      2           .852           .000           1.451
      3         16.271          2.471         282.695
      4           .000           .000           4.844
      5           .000         13.721          61.266
       WATER PRESSURES ON WEDGES
       -------------------------

            LEFTSIDE WEDGES
            ---------------

WEDGE NO.   TOP PRESSURE   BOTTOM PRESSURE
               (KSF)            (KSF)


    1          1.679           3.289
    2          3.289           3.436
            UPLIFT FORCE ON
            STRUCTURAL WEDGE
                (KIPS)
            ---------------

                667.500
```

Figure 51. Output format (Continued)

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
4	2.965	3.160
5	1.422	2.965

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-65.0	32.536	32.280	32.536	80.822
2	-65.0	2.979	6.156	2.979	10.017
3	.000	45.000	1386.616	45.000	667.500
4	17.2	9.131	39.782	9.131	27.963
5	17.2	72.433	166.938	72.433	158.874

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-118.274
2	-16.391
3	31.258
4	14.710
5	88.699

SUM OF FORCES ON SYSTEM ---- .001

FACTOR OF SAFETY ----------- 11.329

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
?

Figure 51. (Concluded)

Error Checks and Messages

Errors in entered data

163. All data entered from the terminal (prompt or keyword) are checked at the time of entry for errors.* If any errors occur, the user is allowed to correct the error and continue with the program. Errors in data entered from a prepared data file, depending on the error, may stop execution of the program. If execution is terminated, the user is notified to check the data file and to start CSLIDE again.

Errors in the solution process

164. Errors encountered during the solution process, depending on the error, may cause execution to terminate. An error message is printed at the terminal to explain the problem.

---

* Input errors refer to incorrect keyword spelling, missing required data, incorrect number of data items entered, commas or other illegal characters, missing blank spaces between data items, or variables with values that are invalid.

APPENDIX A

EXAMPLE PROBLEMS DEMONSTRATING CAPABILITIES OF CSLIDE

Problem	Description	Page
1	Analysis of a retaining wall with surcharge loads. Details on operating the program: data entry, editing, graphics, output.	A4
2	Modeling of a structure with an irregular base and no passive soil wedge. Use of earthquake coefficients and interpretation of results.	A45
3	Control of the elevation of the active failure angle at the structure for analysis of a dam on a rock ledge. Seepage from passive side to active side.	A66
4	User input of precalculated seepage pressures for analysis of a dam. Creating one data file to edit a problem and enter a new problem for analysis.	A78
5	User input of a specific safety factor to obtain the resulting unbalanced forces.	A98
6	Use of the factor of safety ratio to reduce the passive soil force in a CSLIDE analysis.	A110
7	Analysis of a channel-type structure.	A121

Problem 1

Summary

1. This example illustrates the modeling of a simple retaining wall for CSLIDE analysis. Two procedures for data input are demonstrated:

   a. Interactively using a prompting sequence.

   b. From a data file.

2. User control of the echoprint, final results, and graphics is presented.

3. The problem is modified for a second analysis with the keyword method of editing. In this way the user can compare results for different conditions without creating a new data file or exiting the program. Edited data are saved in a new file.

4. A hand check follows each of the CSLIDE solutions. Results of hand and CSLIDE calculations are displayed in a summary table for comparison.

Requirements

5. For this problem, the following are required:

   a. Find the sliding factor of safety (FS) for the wall shown in Figure A1.

   b. Find the FS after vertical surcharges have been added to the left and right sides as shown in Figure A2.

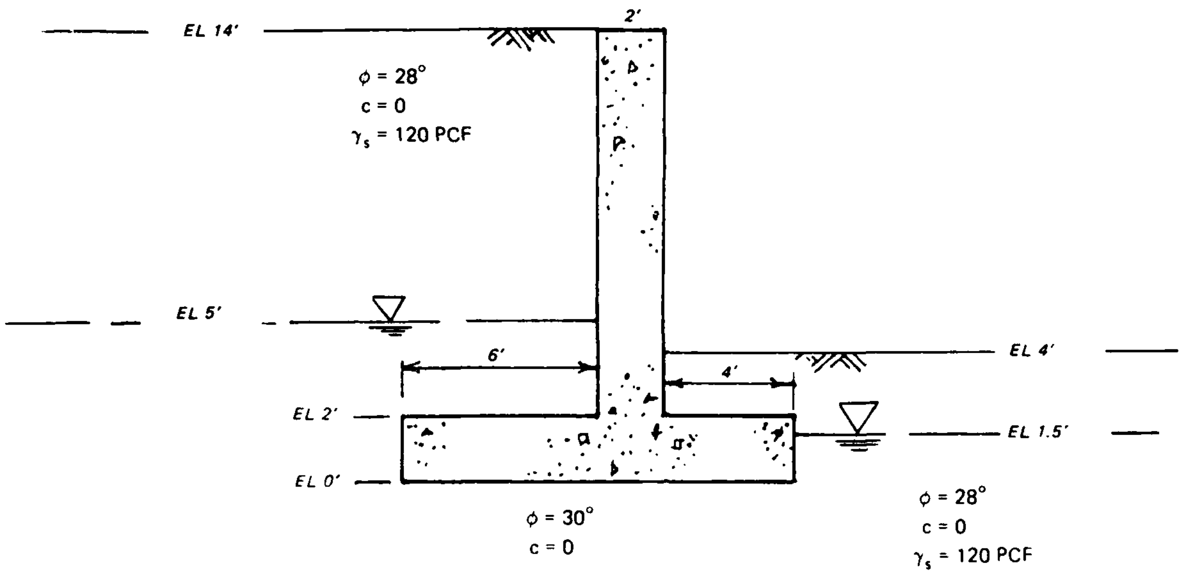


Figure A1. Retaining wall

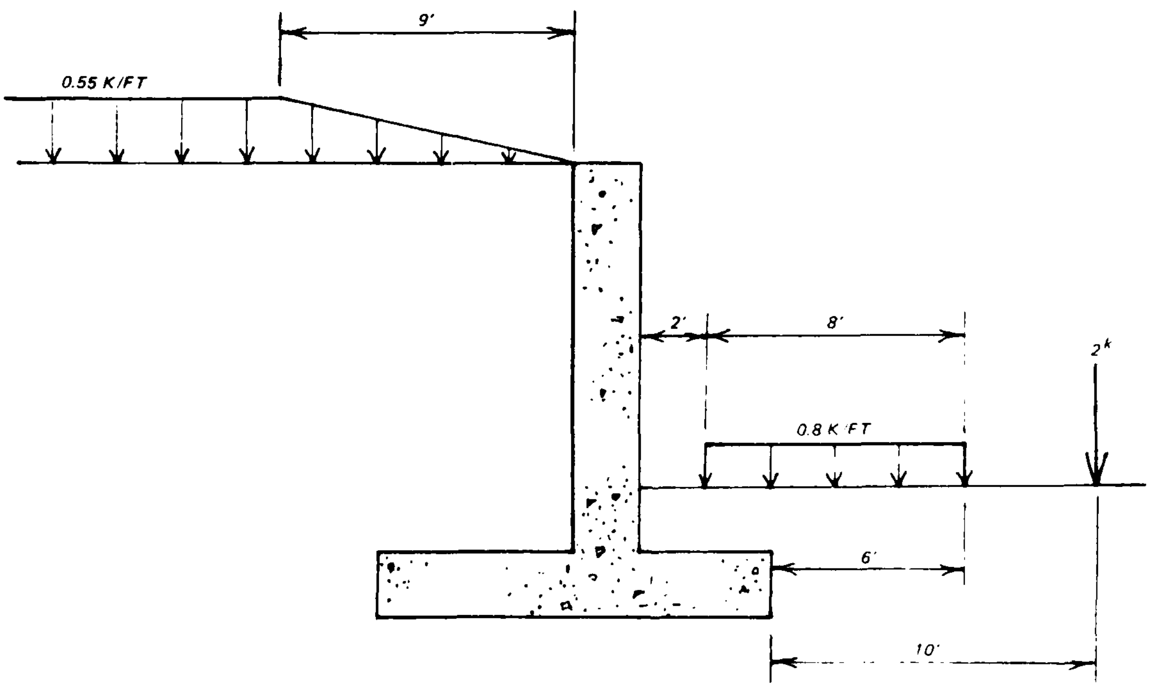


Figure A2. Retaining wall with vertical surcharges

Data Input

6. The procedure for entering data through the prompting sequence is shown on the following pages with user responses underlined. This data is for the first requirement of paragraph 5.

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? T

  DO YOU WANT TO USE A PROMPTING SEQUENCE?
  ENTER 'Y' OR 'N'.
? Y

 ENTER NUMBER OF HEADING LINES (1 TO 4)
? 1

 ENTER 1 HEADER LINES
 (1 TO 70 CHARACTERS PER LINE)

? PROBLEM 1 - RETAINING WALL

     STRUCTURE DESCRIPTION. ENTER THE FOLLOWING DATA

     NUMBER OF XY-COORD.       UNIT WEIGHT
     DEFINING STRUCTURE        OF CONCRETE
          (3 TO 20)               (KCF)

? 8 .150
```

```
      ENTER  8 XY-COORD. TO DEFINE THE STRUCTURE
      (START WITH THE POINT AT THE LOWER LEFT-HAND
       CORNER, AND THEN CONTINUE CLOCKWISE.
       MAX OF 5 COORD PAIRS PER LINE )

? 0 0  0 2  6 2  6 14
? 8 14  8 2  12 2  12 0

 ENTER THE PERCENTAGE OF THE BASE OF THE STRUCTURE
 THAT IS IN COMPRESSION. (A DECIMAL NUMBER)

? 1.0

  DO YOU WANT TO ENTER ELEVATION OF THE
  INTERSECTION OF THE LEFT SIDE FAILURE
  ANGLE AT STRUCTURE ('Y' OR 'N')
? N

 LEFT SIDE SOIL DESCRIPTION.

 ENTER NUMBER OF SOIL LAYERS (1 TO 5)
? 1

 ENTER SOIL LAYER DATA UNDER HEADING. (ONE LINE PER LAYER)

                 INTERNAL                        SATURATED  ELEVATION
  SOIL           FRICTION     COHESION   UNIT WEIGHT    AT
 NUMBER         ANGLE(DEG)     (KSF)        (KCF)     STRUCTURE

? 1  28  0 .120  14

  ENTER NUMBER OF POINTS THAT DESCRIBE
  LAYER 1
? 1
  ENTER COORDINATES DESCRIBING THE SOIL LAYER
  FROM LEFT TO RIGHT
? -500 14

      SOIL BELOW STRUCTURE
      ENTER DATA UNDER HEADINGS.

             FRICTION          COHESION
            ANGLE(DEG)          (KSF)

?   30  0

 RIGHT SIDE SOIL DESCRIPTION.

 ENTER NUMBER OF SOIL LAYERS (1 TO 5)
? 1
```

```
ENTER SOIL LAYER DATA UNDER HEADING. (ONE LINE PER LAYER)

                INTERNAL                      SATURATED  ELEVATION
 SOIL           FRICTION    COHESION     UNIT WEIGHT     AT
NUMBER         ANGLE(DEG)     (KSF)         (KCF)     STRUCTURE


? 1  28  0  .120  4

 ENTER NUMBER OF POINTS THAT DESCRIBE
 LAYER 1
? 1
 ENTER COORDINATES DESCRIBING THE SOIL LAYER
 FROM LEFT TO RIGHT
? 500 4

WATER DATA. ENTER VALUES UNDER HEADING

LEFT SIDE  RIGHT  SIDE   UNIT        SEEPAGE OPTION
ELEVATION   ELEVATION   WEIGHT   -1 = LINE OF CREEP
  (FT)        (FT)      (KCF)     0 = HYDROSTATIC
                                  1 = INPUT PRESSURES


?  5  1.5  .0625  -1

 IS UPLIFT FORCE AT THE BASE OF THE STRUCTURE
 TO BE SPECIFIED? (ENTER 'Y' OR 'N')
? N

 ARE ANY WEDGE FAILURE ANGLES TO BE SPECIFIED?
 (ENTER 'Y' OR 'N')
? N

  ARE ANY LOADS TO BE SPECIFIED?
  ENTER "Y" OR "N"
? N

 ENTER METHOD OF ANALYSIS TO BE USED
   1 FOR SINGLE PLANE ANALYSIS
   2 FOR MULTI PLANE  ANALYSIS
? 1

 DO YOU WANT TO ENTER INITIAL ESTIMATES OF THE FACTOR
 OF SAFETY?  (ENTER 'Y' OR 'N')
? N

DO YOU WANT TO ENTER THE RATIO OF THE
PASSIVE FACTOR OF SAFETY TO THE ACTIVE
FACTOR OF SAFETY, FSP/FSA?
ENTER 'Y' OR 'N'
? N

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? N
```

7. The data file and the procedure for entering the data file for Problem 1 is shown below. The data file must be created before the user starts running the program.

```
NEW,RETWALL
00100 TITL RETAINING WALL ANALYSIS
00110 STRU 8 .15                  (IPT GAMC)
00120 0 0 0 2 6 2 6 14
00130 8 14 8 2 12 2 12 0          (Structure Coordinate Points)
00140 SOLT 1 1 28 0 .120 14       (NLT LPTS PHIL COL GAML STELL)
00150 -500 14                     (Soil Layer Coordinates)
00160 SOST 30 0                   (PHCC CCS)
00170 SORT 1 1 28 0 .120 4        (NRT RPTS PHIR COR GAMR STELR)
00180 500 4                       (Soil Layer Coordinates)
00190 WATR 5 1.5 .0625            (WLL WLR GAMW)
00200 METH 1                      (MEAN)
00210 END
```

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? F

 ENTER DATA FILE NAME (MAXIMUM 7 CHARACTERS)
? RETWALL

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
?
```

Echoprint

8. After all data are entered by prompting, keywords, or a data file, the user may view the input by obtaining an echoprint as shown below:

```
DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
TERMINAL, FILE, BOTH, OR NEITHER?
ENTER 'T', 'F', 'B' OR 'N'
? T
```

```
-----------------------------
  PROGRAM CSLIDE - ECHOPRINT
-----------------------------

DATE:  86/05/14.                       TIME:  14.58.20.

PROBLEM 1 - RETAINING WALL

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE BY LINE OF CREEP, GRADIENT
COMPUTED USING SHORTEST SEEPAGE PATH .

NO OF CORNERS IN STRUCTURE ----------        8
DENSITY OF CONCRETE -----------------    .1500(KCF)
DENSITY OF WATER --------------------    .0625(KCF)
WATER LEVEL LEFT SIDE ---------------     5.00(FT)
WATER LEVEL RIGHT SIDE --------------     1.50(FT)
NO. OF SOIL LAYERS LEFT SIDE --------        1
NO. OF SOIL LAYERS RIGHT SIDE -------        1
```

STRUCTURE INFORMATION

POINT	X-COORD	Y-COORD
1	.00	.00
2	.00	2.00
3	6.00	2.00
4	6.00	14.00
5	8.00	14.00
6	8.00	2.00
7	12.00	2.00
8	12.00	.00

LEFTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	28.00	.0000	.120	14.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	-500.00	14.00

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 30.00
COHESION --------------- .0000

RIGHTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	28.00	.0000	.120	4.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	500.00	4.00

9. After the echoprint, the user has the option to plot the input data.

```
 DO YOU WANT TO PLOT THE INPUT DATA.  ENTER 'Y' OR 'N'.
? Y


        VALID COMMANDS ARE:

          B - BIG PLOT
          A - AXIS
          O - OUTLINE OF PLOTTING AREA
          I - INPUT WINDOW
          P - PICK WINDOW
          G - GRID
          R - REPLOT SAME PICTURE
          T - TOTAL PLOT
          S - ONLY DRAW SOIL, STRUCTURE, WATER,
              AND LOADS
          C - CONTINUE
          ? - VALID COMMANDS
          Q - QUIT
          H - HELP

        TO SELECT AN OPTION, ENTER A CHARACTER
```

10. The letter "H" is entered for an explanation of commands.

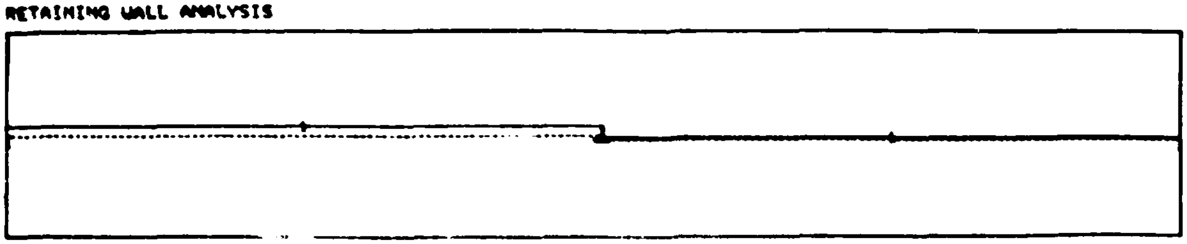
THE FOLLOWING OPTIONS ARE AVAILABLE:

B - DRAWS THE LARGEST PICTURE POSSIBLE OF THE CURRENT WINDOW.
A - PROVIDES AN AXIS FOR THE CURRENT WINDOW. COMMAND ACTS LIKE A TOGGLE SWITCH. ENTER TO GET AN AXIS; ENTER AGAIN TO DELETE AXIS.
O - PROVIDES OUTLINE OF CURRENT PLOTTING AREA. COMMAND ACTS LIKE A TOGGLE SWITCH.
I - ALLOWS THE USER TO INPUT THE DIMENSIONS OF A DESIRED WINDOW.
P - ALLOWS THE USER TO SELECT A WINDOW USING THE CROSS-HAIRS.
G - PROVIDES A GRID IF AN AXIS IS SELECTED. COMMAND ACTS LIKE A TOGGLE SWITCH.
R - REPLOTS THE CURRENT PICTURE.
T - PLOTS THE TOTAL PICTURE.
S - DRAWS ONLY THE SOIL LAYERS, STRUCTURE, WATER LEVELS, AND LOADS. COMMAND ACTS LIKE A TOGGLE SWITCH.
C - EXITS GRAPHICS AND CONTINUES THE SOLUTION.
? - PRINTS LIST OF VALID COMMANDS.
Q - QUIT. EXITS FROM THE PROGRAM. ALL FILES ARE SAVED.
H - THIS COMMAND.

A PICTURE IS NOT DRAWN WHEN THE OPTIONS 'A', 'O', 'S' OR 'G' ARE ENTERED. ONLY THE OPTION IS SET. OPTIONS 'B', 'T', AND 'R' DRAW A PLOT WHEN ENTERED. TO SELECT AN OPTION, ENTER THE CHARACTER ASSOCIATED WITH THE DESIRED OPTION. A CARRIAGE RETURN MAY BE NEEDED DEPENDING ON HOW YOUR PARTICULAR TERMINAL IS SET UP.

11. Following the explanation of the commands, the letter "T" is entered for a total plot of the input data.

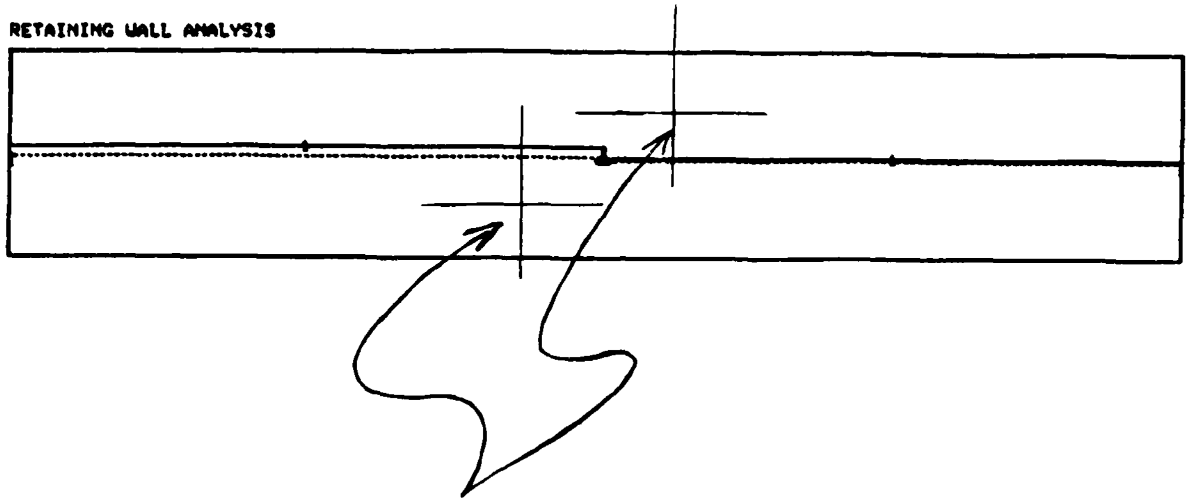
RETAINING WALL ANALYSIS



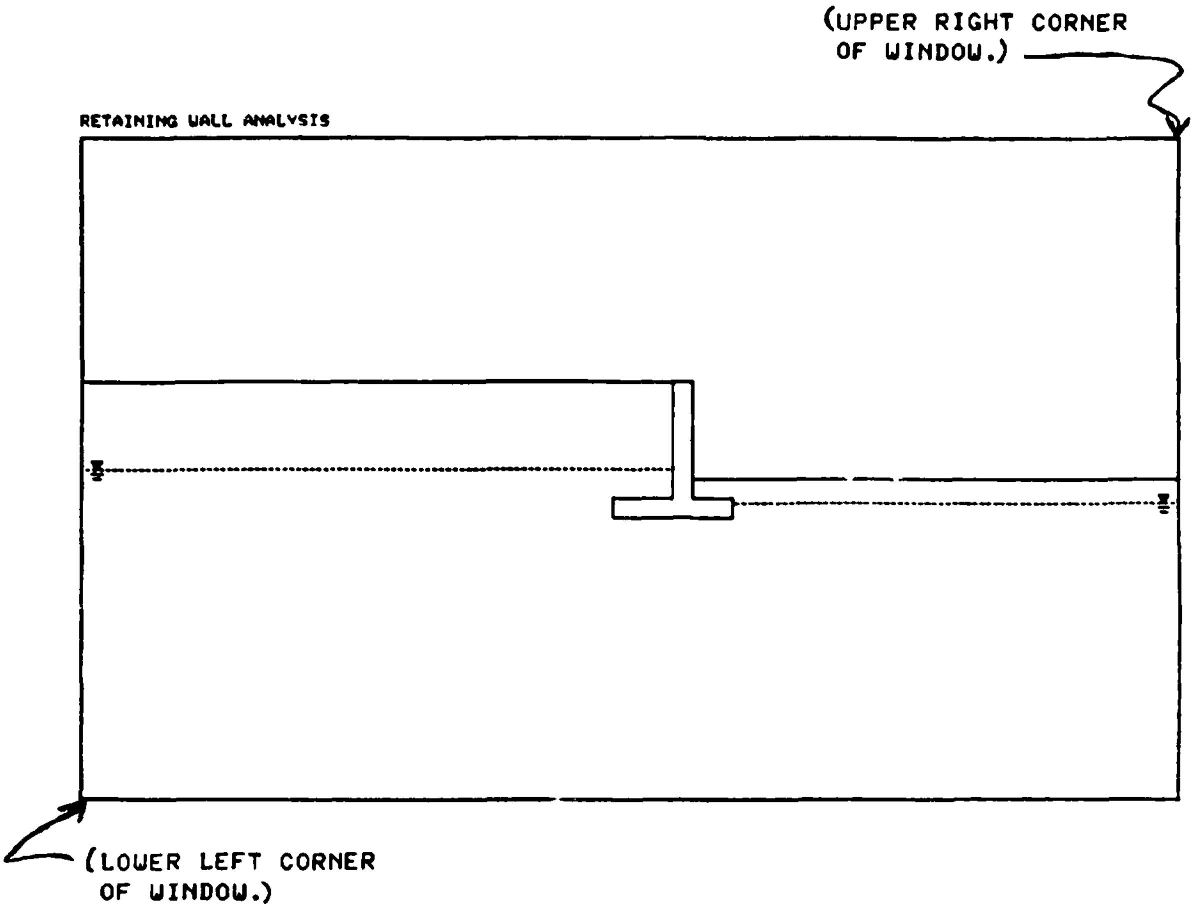
Total plot of input data

12. The size of the plotting area is affected by the soil layer boundaries in the input data. Here, these boundaries are 500 ft to either side of the structure. To enlarge the structure plot, the letter "P" is entered to pick a window.

```
SELECT THE LOWER LEFT CORNER OF WINDOW.
HIT ANY CHARACTER.
SELECT THE UPPER RIGHT CORNER OF WINDOW.
HIT ANY CHARACTER.
```



13. Crosshairs on the terminal screen are used to select the lower left and upper right corners of the new plotting area. (The results of "windowing" are shown in the following plot.)



Plot of input data

To continue the solution, it is necessary to enter "C".

14. With the graphics of Problem 1 completed, the program continues.

```
DO YOU WISH TO CONTINUE SOLUTION?
ENTER 'Y' OR 'N'
? Y

 IS OUTPUT TO GO TO YOUR TERMINAL, A FILE,
 OR BOTH? ENTER "T","F" OR "B"
? T

DO YOU WANT TO PRINT TEMPORARY RESULTS?
ENTER 'Y' OR 'N'
? N
```

```
------------------------------------
   PROGRAM CSLIDE - FINAL RESULTS
------------------------------------

 DATE:  86/05/14.                    TIME:  14.59.40.

 PROBLEM 1 - RETAINING WALL


 SINGLE FAILURE PLANE ANALYSIS

 SEEPAGE FORCE COMPUTED BY LINE OF CREEP
```

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	9.600
3	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.253

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	.253
12.00	.111

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.000	.111

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-53.664	17.379	8.650	6.207	.786
2	.000	12.000	7.200	12.000	2.189
3	36.336	6.751	1.305	2.532	.141

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-6.653
2	4.950
3	1.703

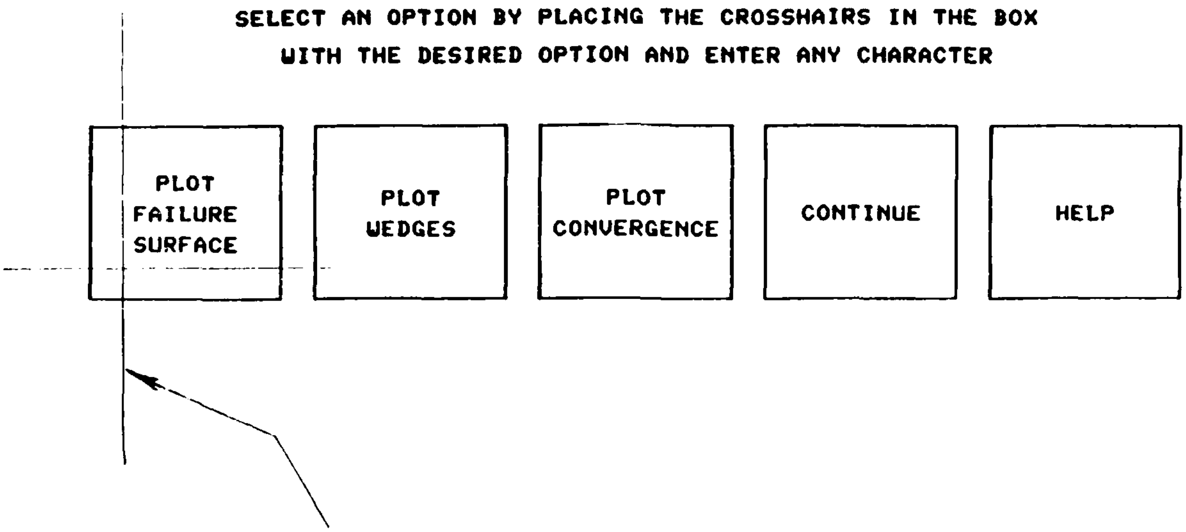
SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 1.704

15. After the output is complete, the user may select to plot the results.

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'
?Y

16. When the output graphics Menu 1 appears on the screen, an option can be selected as shown below.



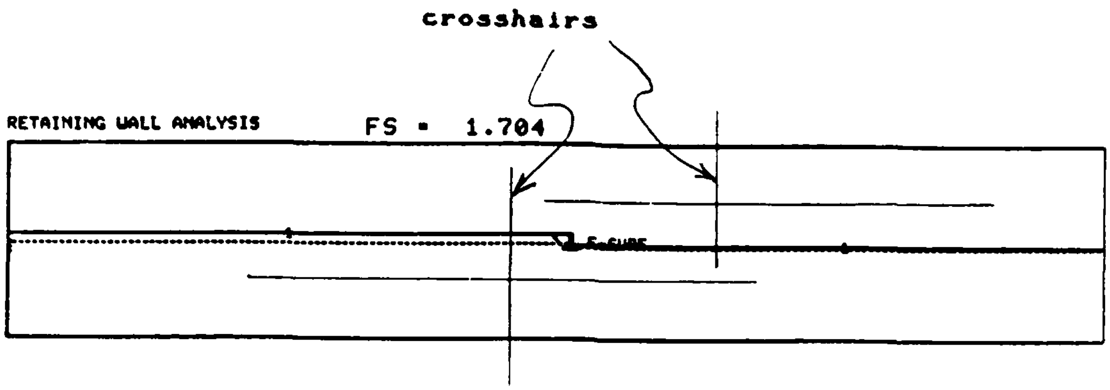
Crosshairs are used to select a plotting option.

17. After selecting the failure surface option, a list of valid commands is printed.

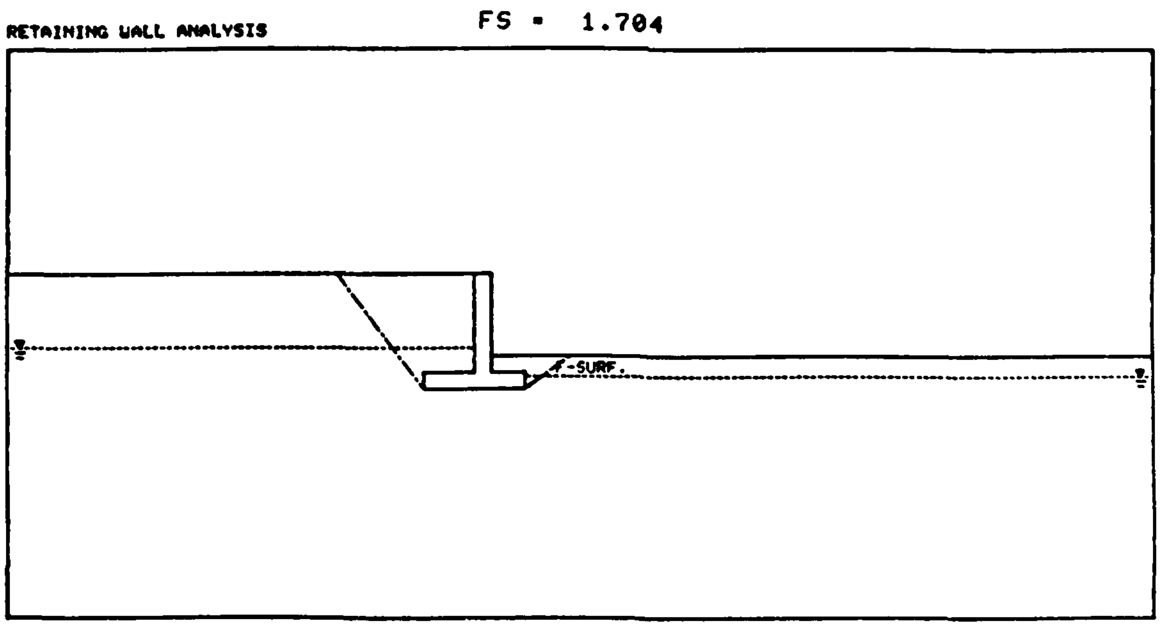
```
VALID COMMANDS ARE:

 B - BIG PLOT
 A - AXIS
 O - OUTLINE OF PLOTTING AREA
 I - INPUT WINDOW
 P - PICK WINDOW
 G - GRID
 R - REPLOT SAME PICTURE
 T - TOTAL PLOT
 S - ONLY DRAW SOIL, STRUCTURE, AND WATER
 W - DRAW WATER PRESSURES
 C - CONTINUE
 ? - VALID COMMANDS
 Q - QUIT
 H - HELP

TO SELECT AN OPTION, ENTER A CHARACTER
```

18. From the valid commands for selecting an option, "T" is entered for a total plot, then "P" is entered to pick a window.

SELECT THE LOWER LEFT CORNER OF WINDOW.
HIT ANY CHARACTER.
SELECT THE UPPER RIGHT CORNER OF WINDOW.
HIT ANY CHARACTER.



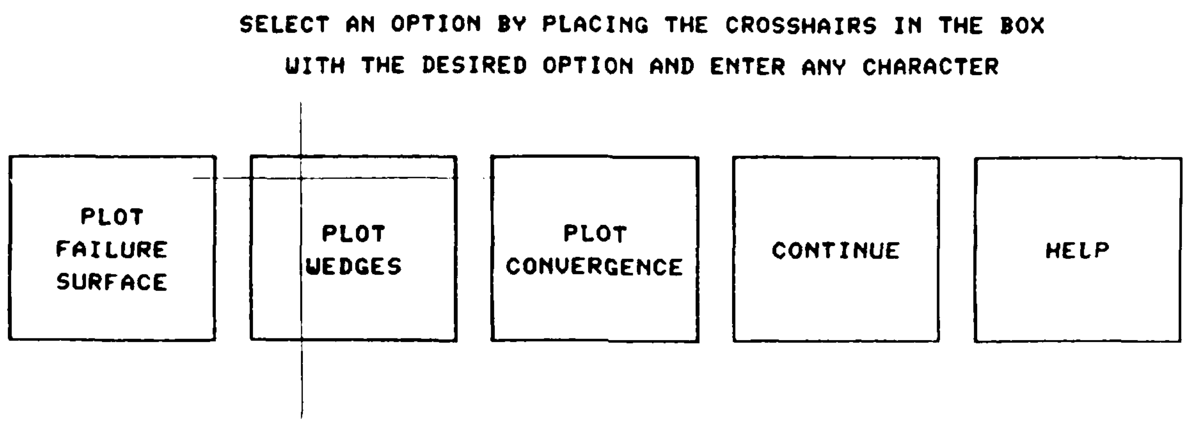
19. A total plot of the failure surface and the window selection instructions are displayed above. The result of the window selection is shown in the following plot.



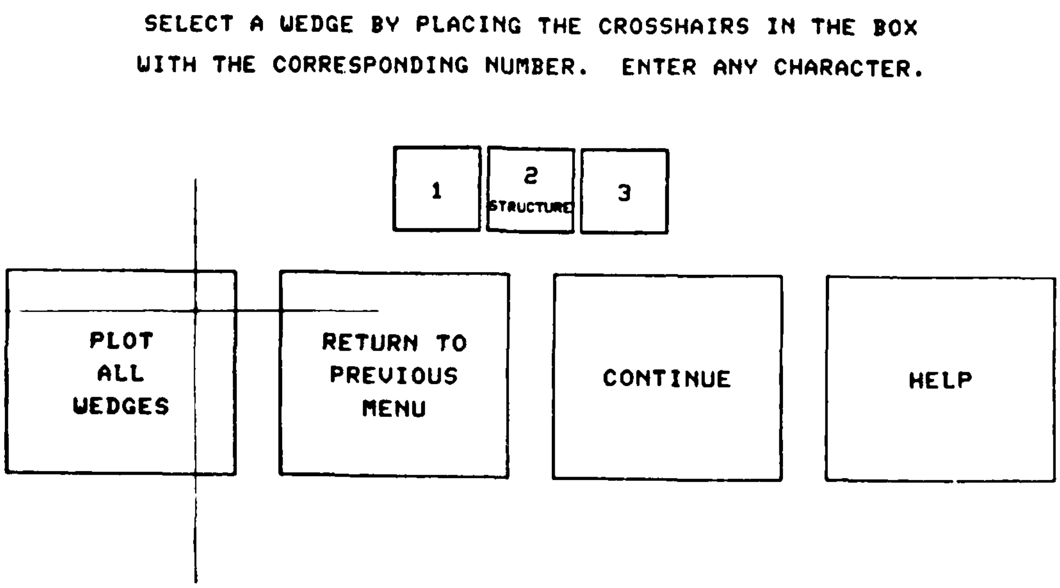
Enter "C" to continue.

20. The program returns to Menu 1. If the option to plot wedges is chosen, as shown with the crosshairs in the following drawing, a second output graphics menu appears. Options on Menu 2 are chosen by the crosshairs on the screen, just as is done with Menu 1. The option to plot all wedges is chosen from Menu 2.

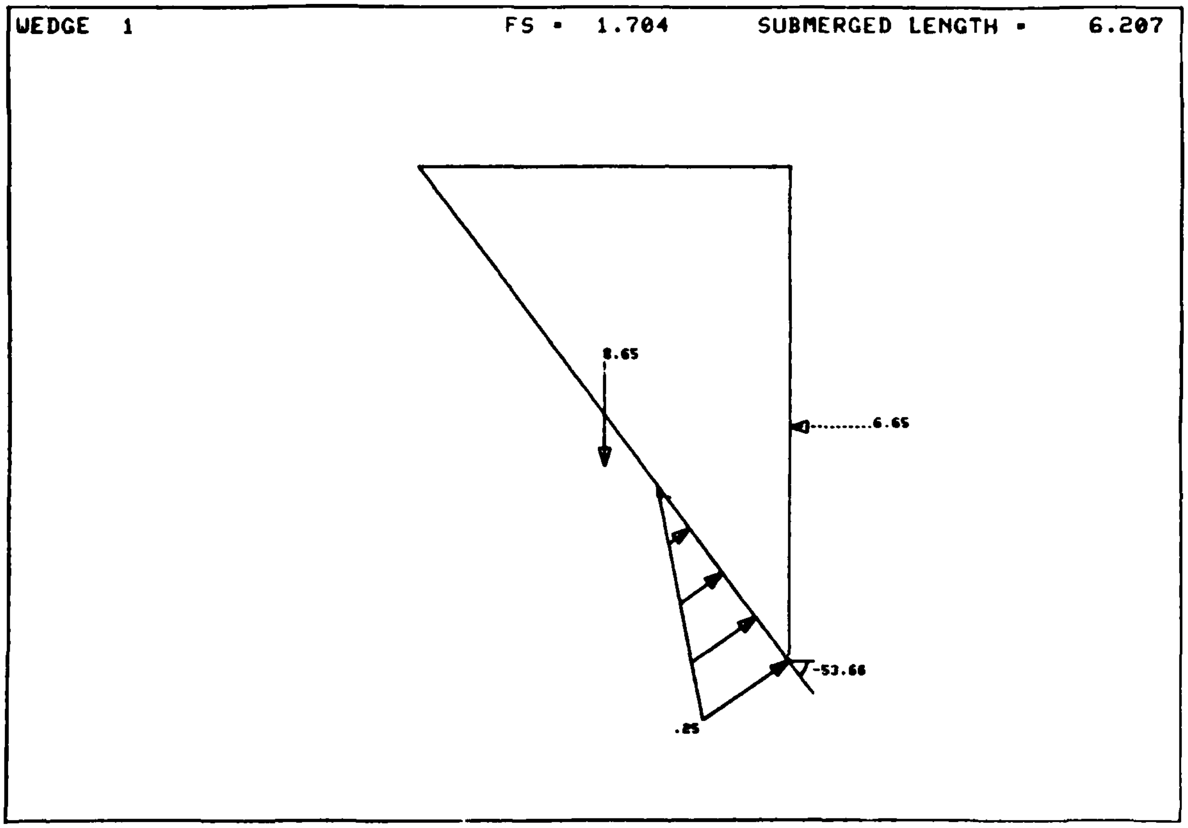
Menu 1



Menu 2

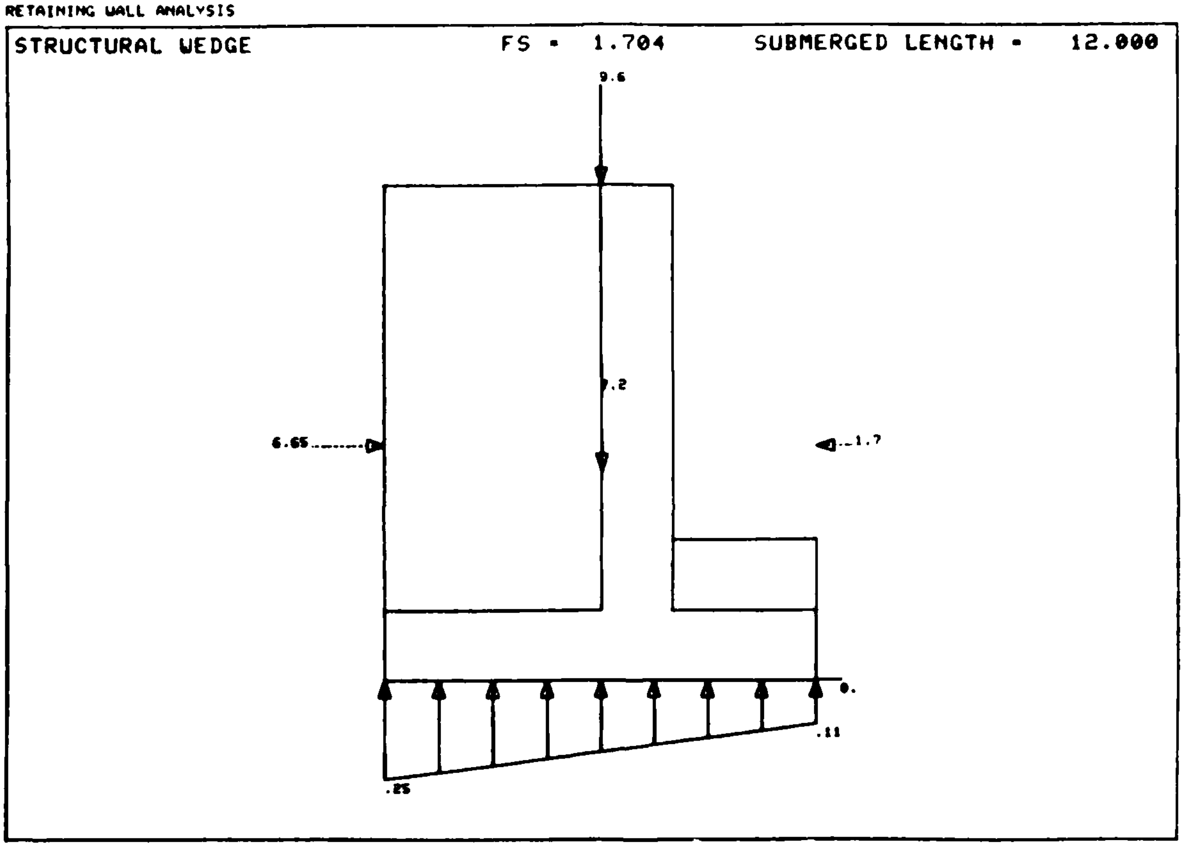


RETAINING WALL ANALYSIS



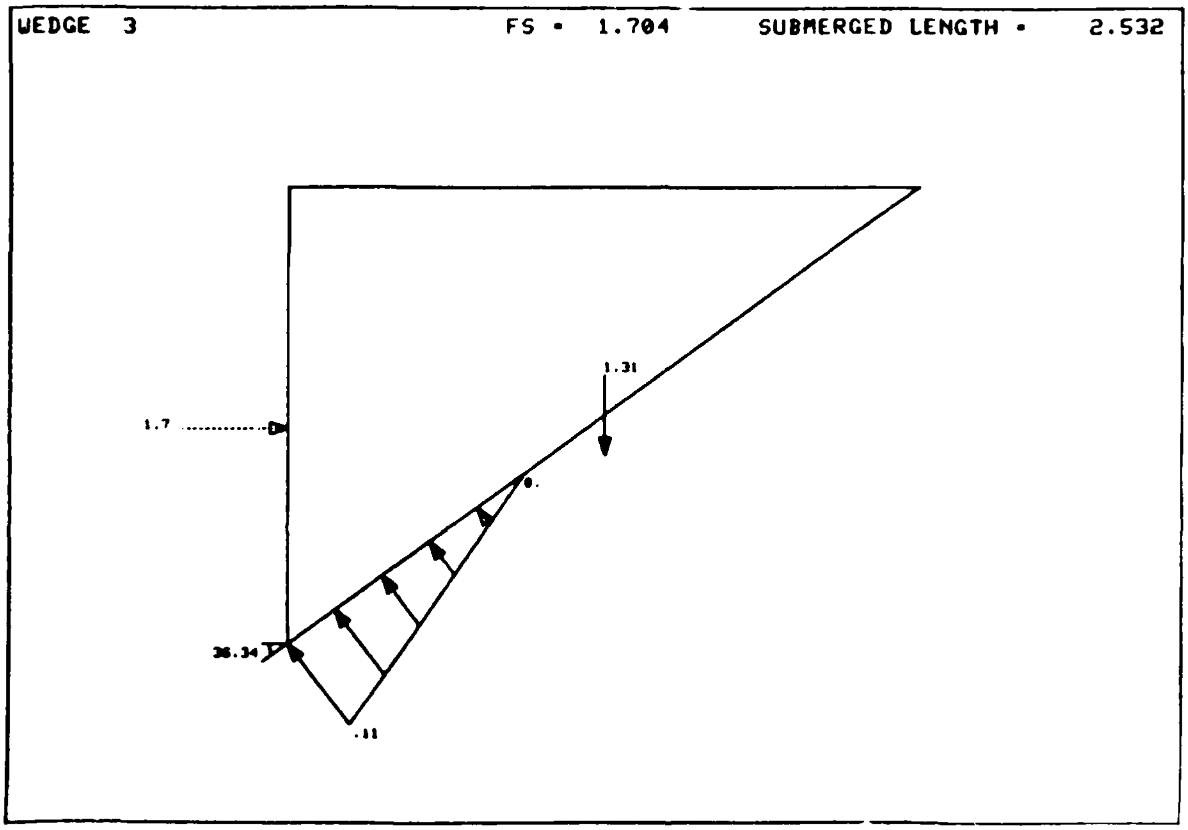
Enter "C" to continue to the next wedge.

RETAINING WALL ANALYSIS



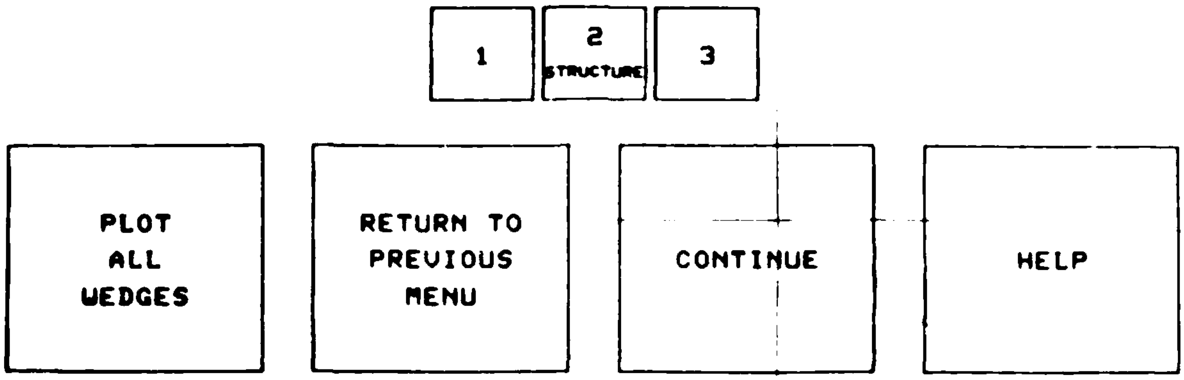
Enter "C" to continue to the next wedge.

RETAINING WALL ANALYSIS



Enter "C" to continue to Menu 2. Since this is the last wedge in the system, Menu 2 is redrawn.

SELECT A WEDGE BY PLACING THE CROSSHAIRS IN THE BOX
WITH THE CORRESPONDING NUMBER. ENTER ANY CHARACTER.

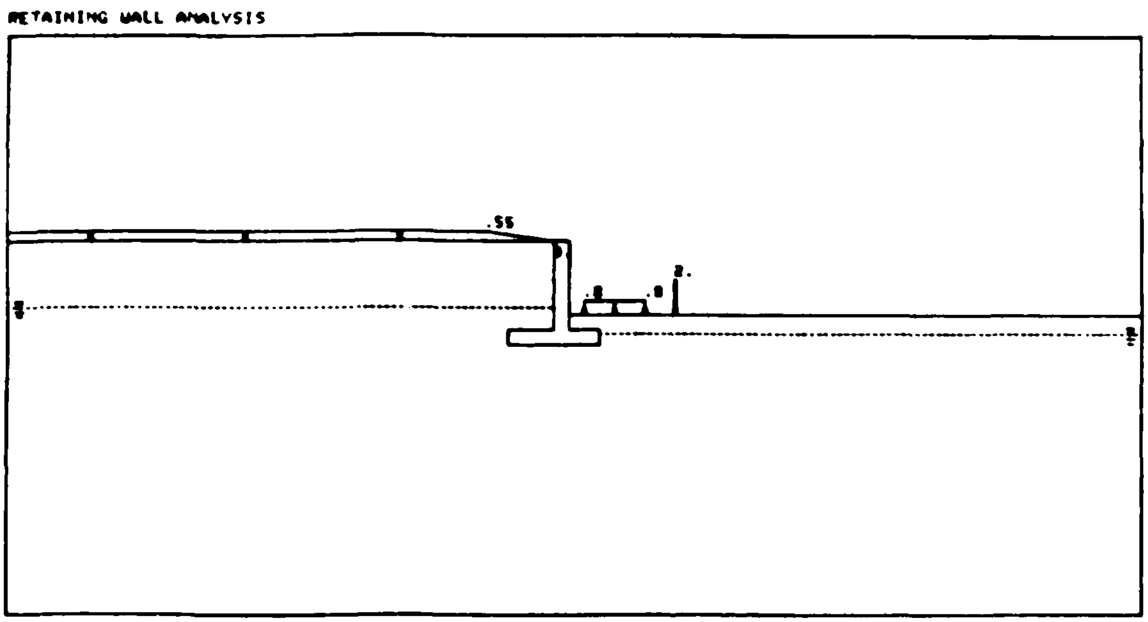


Continue
with the
program

21. The option to continue with the program is selected. After exiting the output graphics, the user is given the option to edit data and reanalyze the problem. The data will be altered to solve the problem shown in Figure A2, and the requirement in paragraph 5b. (The data is altered by using the keyword method of editing to apply vertical loads on the left and right sides of the structure. After editing, the new input data is plotted.)

```
             DO YOU WISH TO EDIT DATA AND RERUN PROBLEM?
             (ENTER 'Y' OR 'N')
            Y

             DO YOU WANT A CURRENT LISTING OF YOUR DATA?
             ENTER 'Y' OR 'N'
            ? N

             DO YOU WANT TO EDIT USING KEYWORDS
             OR SECTIONS ? (ENTER 'K' OR 'S')
            ? K

             ENTER KEYWORD. TYPE 'END' TO EXIT, 'LIST'
             TO LIST KEYWORDS
Ramp Load-? VRLO 6 9 .55
```

```
               NEXT?
Strip Load-? VSLO 10 8 .8

               NEXT?
Point Load-? VPLO 22 2

               NEXT?
             ? END

               DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
               TERMINAL, FILE, BOTH, OR NEITHER?
               ENTER 'T', 'F', 'B' OR 'N'
             ? N

               DO YOU WANT TO PLOT THE INPUT DATA.  ENTER 'Y' OR 'N'.
             ? Y
```



"Window" of the plot of modified input data

The letter "C" is entered to continue with the solution. A new file of edited data, "OUTWAL", is created to save current data. This file is shown in paragraph 26. (After saving the edited data in a file, the user can continue with the solution of the problem.)

```
 DO YOU WANT TO SAVE CURRENT DATA IN A FILE?
 ENTER 'Y' OR 'N'.
? Y

 ENTER A FILENAME TO SAVE CURRENT DATA (7 CHAR. MAX.)
? OUTWAL

DO YOU WISH TO CONTINUE SOLUTION?
ENTER 'Y' OR 'N'
? Y

 IS OUTPUT TO GO TO YOUR TERMINAL, A FILE,
 OR BOTH? ENTER "T","F" OR "B"
? T

DO YOU WANT TO PRINT TEMPORARY RESULTS?
ENTER 'Y' OR 'N'
? N


------------------------------------
   PROGRAM CSLIDE - FINAL RESULTS
------------------------------------


 DATE:  86/05/14.                          TIME:  15.03.02.

 PROGRAM 1 - RETAINING WALL

 SINGLE FAILURE PLANE ANALYSIS

 SEEPAGE FORCE COMPUTED BY LINE OF CREEP


                 HORIZONTAL LOADS
                 ----------------          VERTICAL
    WEDGE       LEFT   SIDE     RIGHT SIDE     LOAD
    NUMBER       (KIPS)          (KIPS)       (KIPS)
 ----------------------------------------------------


      1          .000            .000          5.701
      2          .000            .000         12.300
      3          .000            .000          4.800


          WATER PRESSURES ON WEDGES
          -------------------------

               LEFTSIDE WEDGES
               ---------------

 WEDGE NO.  TOP PRESSURE  BOTTOM PRESSURE
               (KSF)           (KSF)


     1          .000            .253
```

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	.253
12.00	.111

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.000	.111

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-52.186	17.722	9.127	6.329	.802
2	.000	12.000	7.200	12.000	2.189
3	21.802	10.770	2.400	4.039	.225

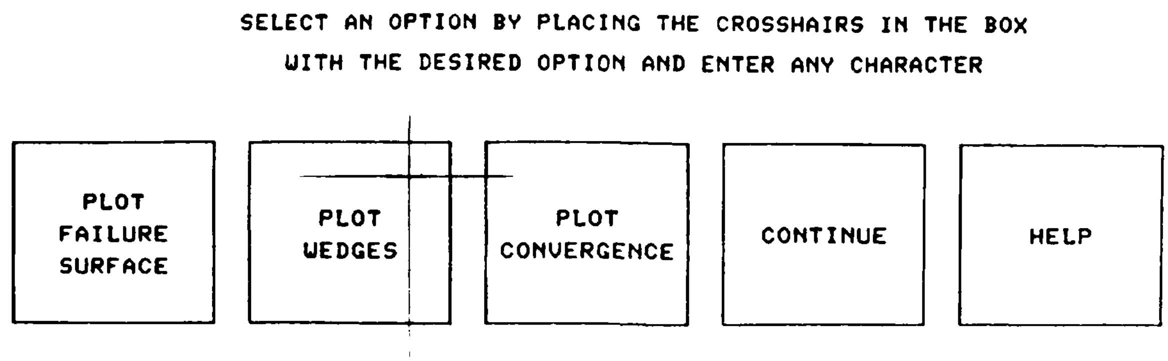
WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-11.029
2	5.475
3	5.554

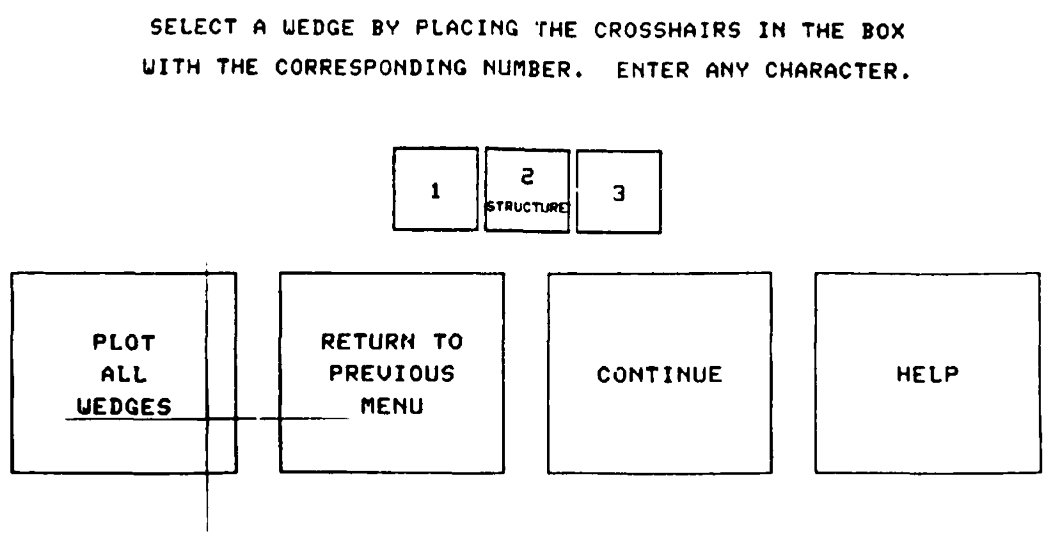
SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 1.825

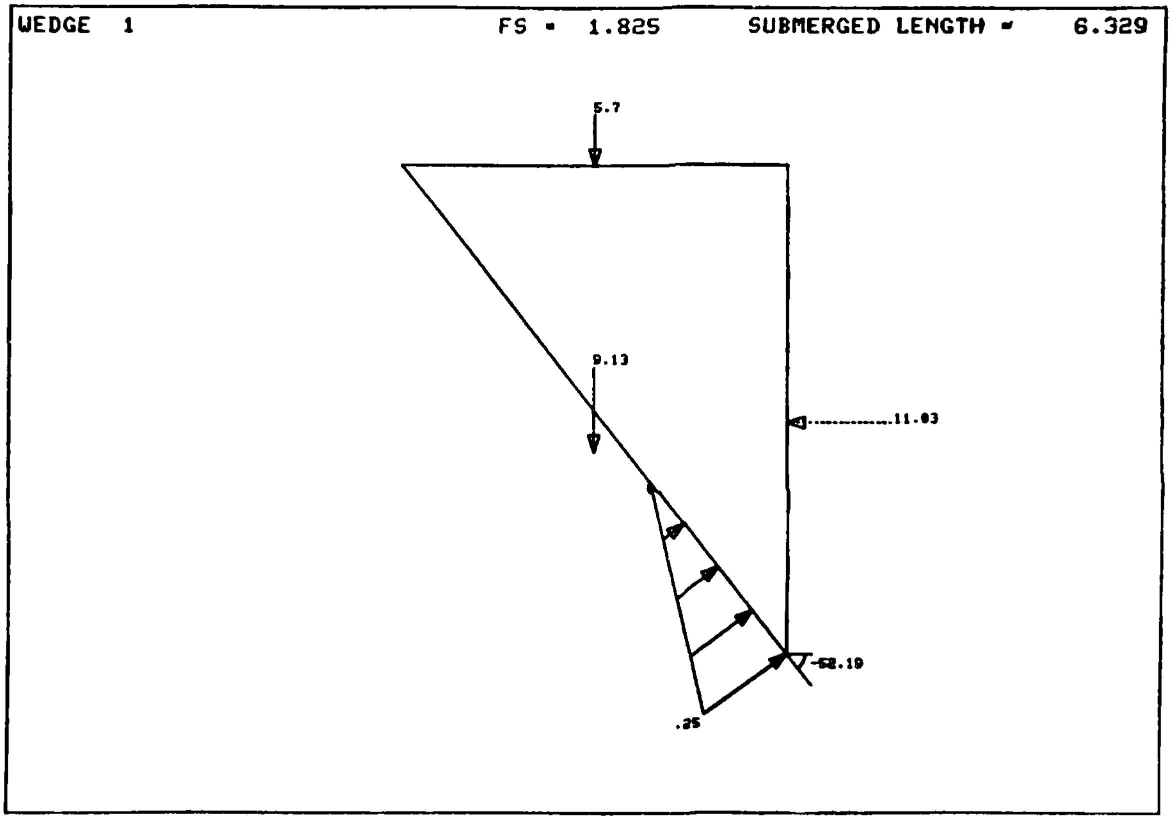
DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
? Y

22. After the solution is complete, the results may be plotted. Menu 1 of the output graphics appears below. Wedges are chosen to be plotted, as indicated with the crosshairs. Menu 2 appears with the wedge plotting commands. The option to plot all wedges is chosen.



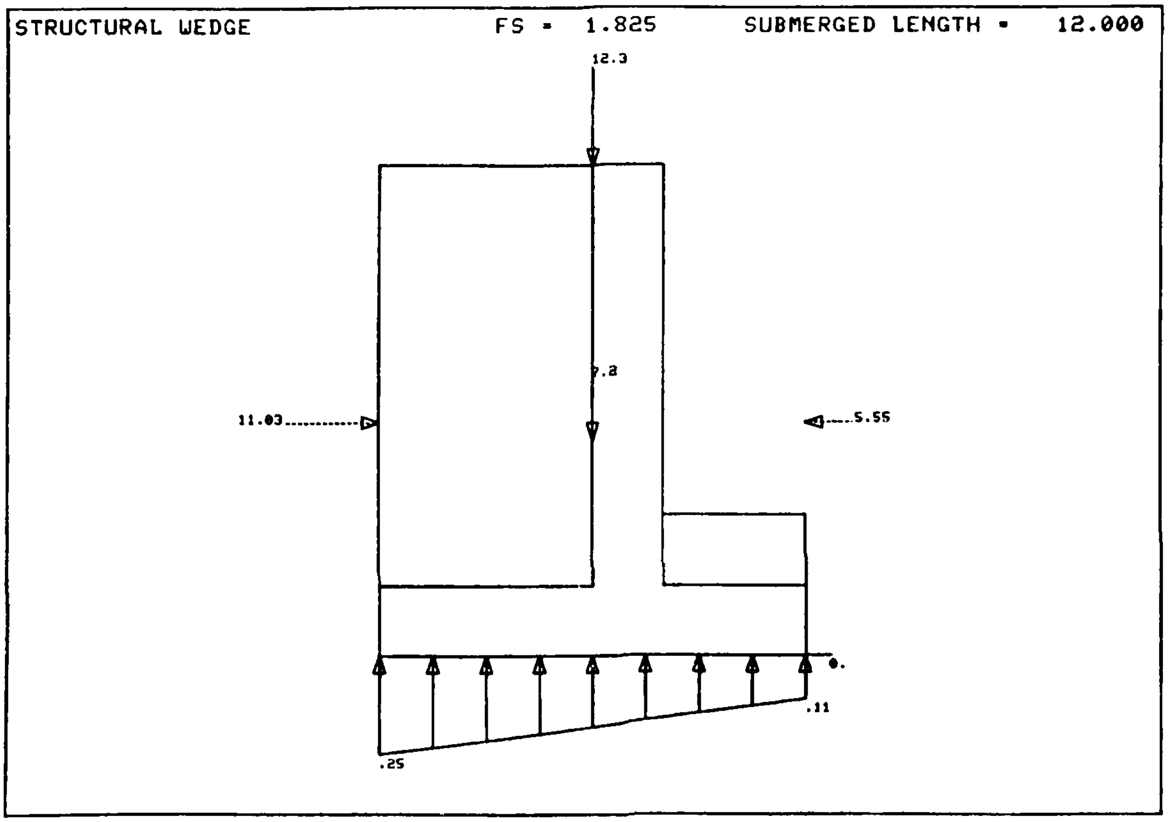


RETAINING WALL ANALYSIS



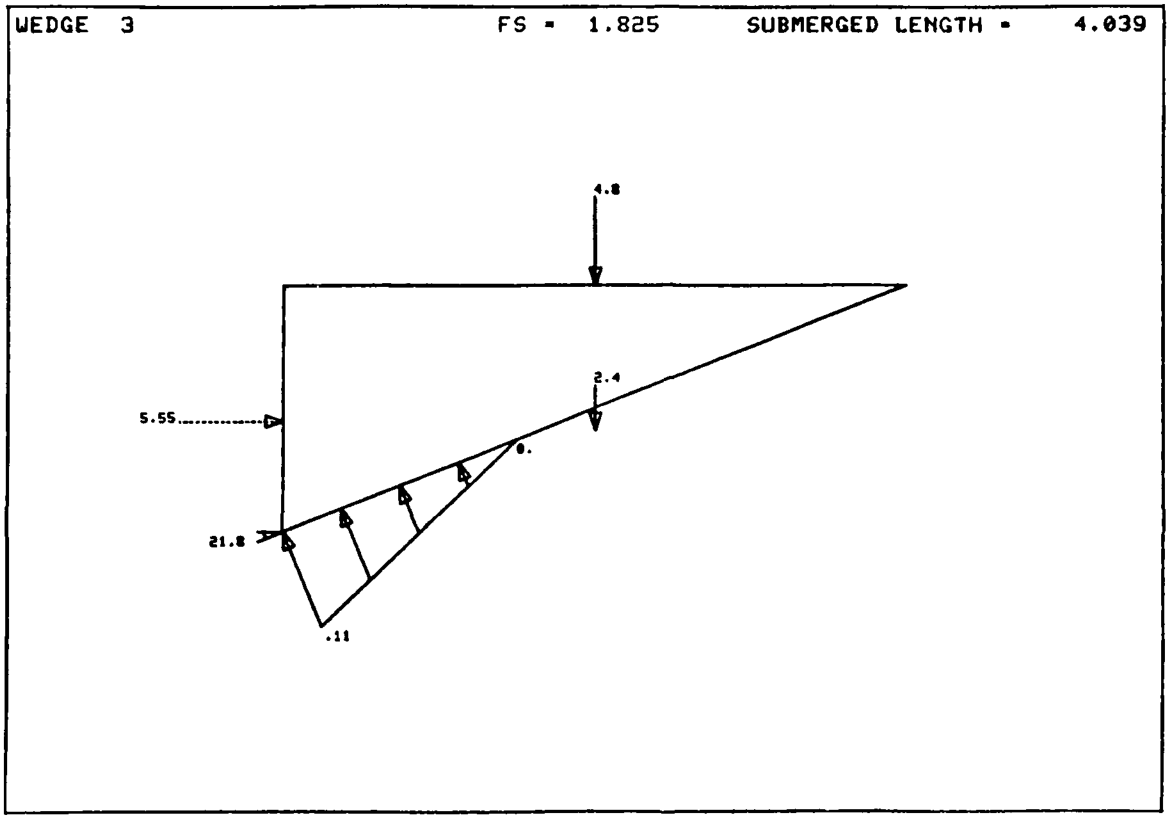
Enter "C" to continue.

RETAINING WALL ANALYSIS



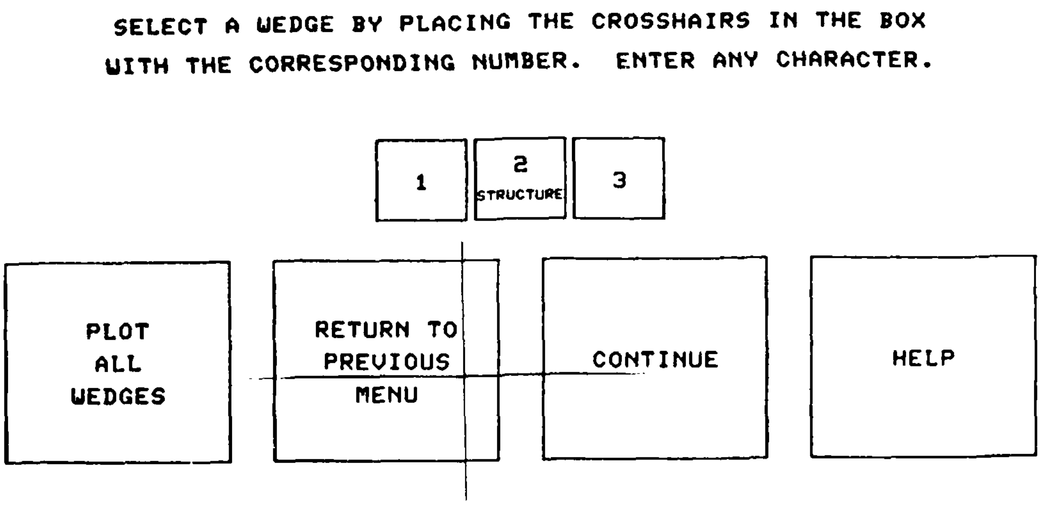
Enter "C" to continue.

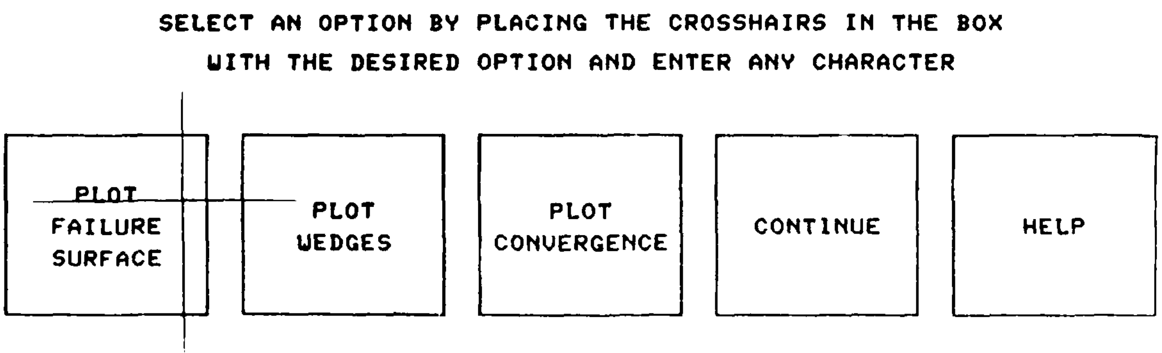
RETAINING WALL ANALYSIS

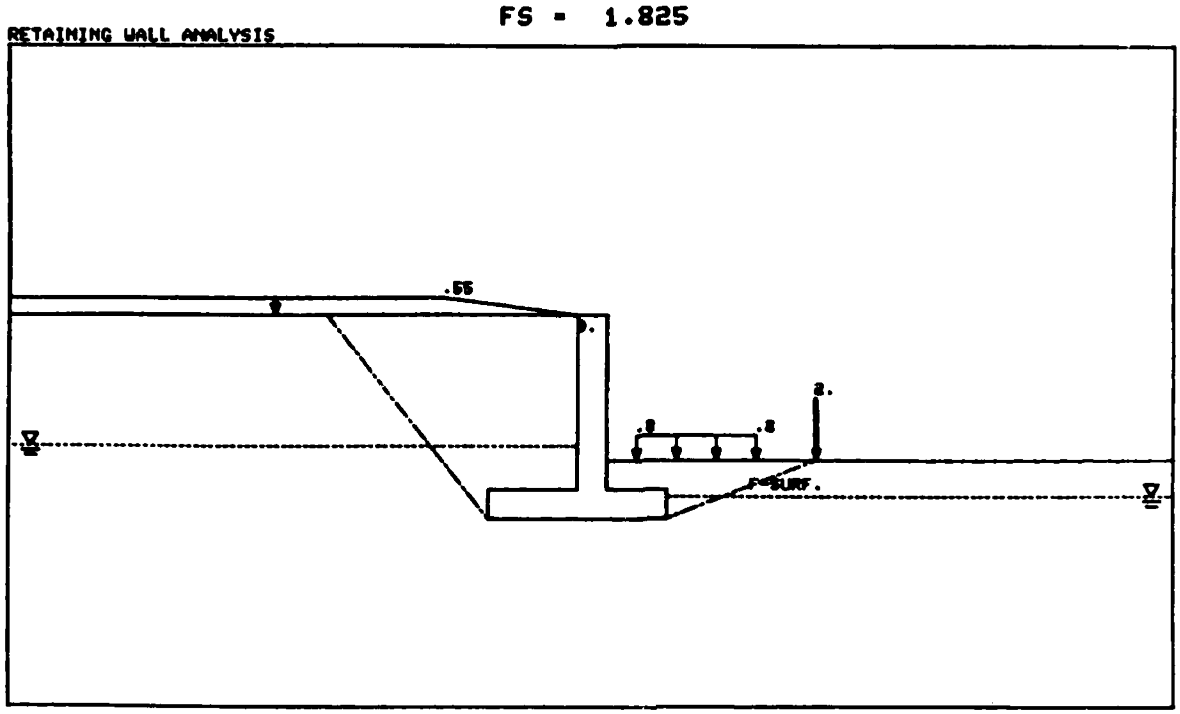


Enter "C" to continue.

23. After all wedges are plotted, Menu 2 appears again. The command to return to Menu 1 is selected and Menu 1 appears. The option to plot the failure surface is chosen.







Enter "C" to continue

24. The plot of the failure surface is shown after a window has been selected. Graphics continues with a return to Menu 1. The command is given to continue with the program.

SELECT AN OPTION BY PLACING THE CROSSHAIRS IN THE BOX WITH THE DESIRED OPTION AND ENTER ANY CHARACTER

PLOT FAILURE SURFACE	PLOT WEDGES	PLOT CONVERGENCE	CONTINUE	HELP

Termination of Program

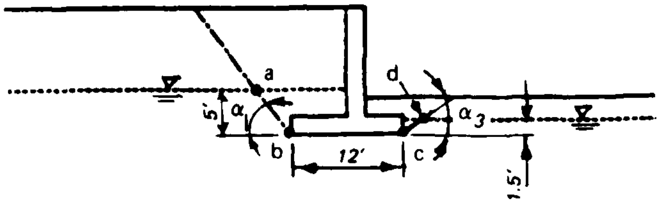
25. No more editing or analysis is desired and the program is allowed to terminate.

```
 DO YOU WISH TO EDIT DATA AND RERUN PROBLEM?
 (ENTER 'Y' OR 'N')
?
  ANSWER MUST BE 'Y' OR 'N' - RETRY
? N

 DO YOU WANT TO MAKE ANOTHER RUN?
 (ENTER 'Y' OR 'N')
? N
 * * * NORMAL TERMINATION * * *
$REVERT.CCL
/
```

26. File "OUTWAL" was created by CSLIDE to save edited data for Problem 1, requirement b. This file is shown below.

```
/OLD,OUTWAL
/LIST
010 TITL PROBLEM 1 - RETAINING WALL
020 STRU  8      .15000         .00       1.00000
030            .00          .00
040            .00         2.00
050           6.00         2.00
060           6.00        14.00
070           8.00        14.00
080           8.00         2.00             Default values
090          12.00         2.00
100          12.00          .00
110 SOLT  1  1        28.00       .00000       .12000       14.00
120        -500.00       14.00
130 SORT  1  1        28.00       .00000       .12000        4.00
140         500.00        4.00
150 SOST        30.00        .00000
160 METH  1
170 WATR         5.00         1.50       .06250        -1.
180 FACT          .50         1.50       1.0000
190 VPLO        22.00       2.0000
200 VSLO        10.00         8.00        .8000
210 VRLO         6.00         9.00        .5500
220 END

                                                 Default values
```

27. Hand-checked calculations of CSLIDE results follow the termination of the program.



Hand Check of CSLIDE Results--Problem 1, No Vertical Loads

Water Pressures

$$\text{Pressure} = P = \gamma_w \left[\begin{array}{l}\text{Headwater}\\\text{Elevation}\end{array} - \begin{array}{l}\text{Elevation of}\\\text{Point of}\\\text{Interest}\end{array} - (i) \times \left(\begin{array}{l}\text{Length of}\\\text{Seepage}\\\text{Path}\end{array} \right) \right]$$

$$\begin{array}{l}\text{Seepage}\\\text{Gradient}\end{array} = i = \frac{\Delta H}{L} = \frac{(5' - 1.5')}{(5' + 12' + 1.5')} = 0.189189$$

L = Total Length of Seepage Path

= Wetted Perimeter of Structural Wedge

Length of Seepage Path = Linear Distance Along Structural Wedge From Left Side Water Elevation to Point of Interest

Wedge 1:

$P_a = 0$

$P_b = \gamma_w[5' - 0' - i(5')] = 0.253$ ksf

Wedge 2:

$P_b = 0.253$ ksf

$P_c = \gamma_w[5' - 0' - i(5' + 12')] = 0.111$ ksf

Wedge 3:

$P_c = 0.111$ ksf

$P_d = 0$

(Continued)

(Sheet 1 of 3)

Hand Check (Continued)

Angles

$$\alpha_1 = -\left(45 + \frac{\phi_d}{2}\right)$$

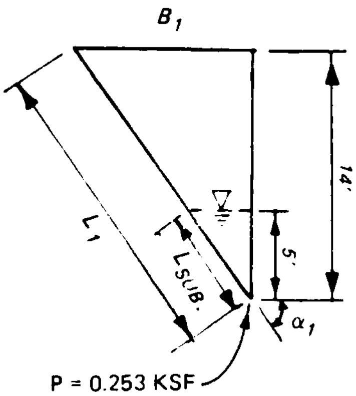
$$\phi_d = \tan^{-1}\left(\frac{\tan\ \phi_1}{FS}\right) = \tan^{-1}\left(\frac{\tan\ 28°}{1.704}\right) = 17.33°$$

$$\alpha_1 = -53.665°$$

$\alpha_2 = 0.00°$ (inclination of structure base)

$$\alpha_3 = \left(45 - \frac{\phi_d}{2}\right) = 36.335°$$

Wedge 1



$$L_1 = \frac{14'}{\sin\ \alpha_1} = 17.38'$$

$$L_{submerged} = L_{sub} = \frac{5'}{\sin\ \alpha_1} = 6.21'$$

$$\text{Width} = B_1 = L_1\ \cos\ \alpha_1 = 10.30'$$

$$\text{Weight}_1 = \frac{1}{2}\ (10.30)(14')(0.12\ \text{kcf}) = 8.65^k$$

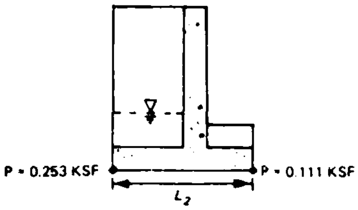
$$\text{Uplift}_1 = \frac{1}{2}\ (0 + 0.253)(6.21') = 0.786^k$$

$$\text{Net force,}\quad P_0 - P_1 = \frac{(8.65\ \cos\ \alpha_1 - 0.786)\ \dfrac{\tan\ \phi_1}{1.704} + 8.65\ \sin\ \alpha_1}{\cos\ \alpha_1 - \sin\ \alpha_1\left(\dfrac{\tan\ \phi_1}{1.704}\right)} = -6.65^k$$

(Continued) (Sheet 2 of 3)

Hand Check (Concluded)

Wedge 2



$$\text{Weight}_2 = [(2 \times 12) + (2 \times 12)]\ 0.150 = 7.20^k$$

$$\text{Uplift}_2 = \frac{1}{2}\ (0.253 + 0.111)(12') = 2.184^k$$

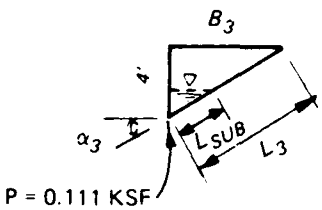
$$L_2 = L_{sub} = 12'$$

$$\text{Vertical loads} = V_2 = \text{Soil} = [(6' \times 12') + (2' \times 4')](0.120\ \text{kcf}) = 9.6^k$$

$$\text{Net force},\quad P_1 - P_2 = \frac{[(7.2 + 9.6)\cos\alpha_2 - 2.184]\ \dfrac{\tan\phi_2}{1.704} + (7.2 + 9.6)\sin\alpha_2}{\cos\alpha_2 - \sin\alpha_2\left(\dfrac{\tan\phi_2}{1.704}\right)}$$

$$= 4.95^k$$

Wedge 3



$$B_3 = \frac{4'}{\tan\alpha_3} = 5.44'$$

$$L_3 = \frac{4'}{\sin\alpha_3} = 6.75'$$

$$L_{sub} = \frac{1.5'}{\sin\alpha_3} = 2.53'$$

$$\text{Weight}_3 = \frac{1}{2}\ (5.44 \times 4)(0.120\ \text{kcf}) = 1.31^k$$

$$\text{Uplift}_3 = \frac{1}{2}\ (0 + 0.111)(2.53) = 0.140^k$$

$$\text{Net force},\quad P_2 - P_3 = \frac{(1.31\cos\alpha_3 - 0.14)\ \dfrac{\tan\phi_3}{1.704} + 1.31\sin\alpha_3}{\cos\alpha_3 - \sin\alpha_3\left(\dfrac{\tan\phi_3}{1.704}\right)} = 1.71^k$$

$$\text{Sum of net forces} = -6.65 + 4.95 + 1.71 = 0.010^k$$

(Sheet 3 of 3)

Table A1

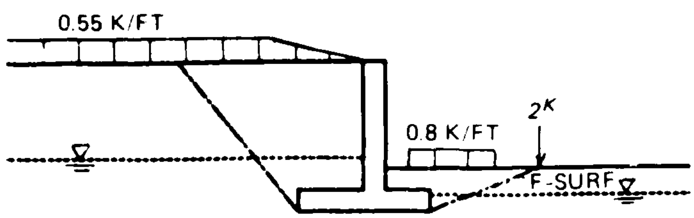
Summary of Problem 1, No Vertical Loads--CSLIDE and Hand Calculations

Wedge Number	Horizontal Loads: Left Side (kips) CSLIDE	Hand	Right Side (kips) CSLIDE	Hand	Vertical Load (kips) CSLIDE	Hand	Failure Angle (deg) CSLIDE	Hand
1	0.000	0.0	0.000	0.0	0.000	0.0	-53.664	-53.665
2	0.000	0.0	0.000	0.0	9.600	9.60	0.000	0.0
3	0.000	0.0	0.000	0.0	0.000	0.0	36.336	36.335

Wedge Number	Total Length (ft) CSLIDE	Hand	Weight of Wedge (kips) CSLIDE	Hand	Submerged Length (ft) CSLIDE	Hand	Uplift Force (kips) CSLIDE	Hand
1	17.379	17.38	8.650	8.65	6.207	6.21	0.786	0.786
2	12.000	12.00	7.200	7.20	12.000	12.00	2.189	2.184
3	6.751	6.75	1.305	1.31	2.532	2.53	0.141	0.140

Wedge Number	Net Force on Wedge (kips) CSLIDE	Hand
1	-6.653	-6.65
2	4.950	4.95
3	1.703	1.71
Sum of Forces	0.000	0.01

FACTOR OF SAFETY = 1.704



Hand Check of CSLIDE Results--Problem 1, Vertical Loads

Angles

The expression, $\left(45 \pm \frac{\phi_d}{2}\right)$, cannot be used to check these failure angles. The nonuniform sur-charges over the wedge surfaces invalidate this expression. The angles calculated in CSLIDE are assumed correct. Remaining hand checks are based on CSLIDE angles.

Water Pressures

Pressures from the first analysis are:

$$P_{heel} = 0.253 \text{ ksf}$$

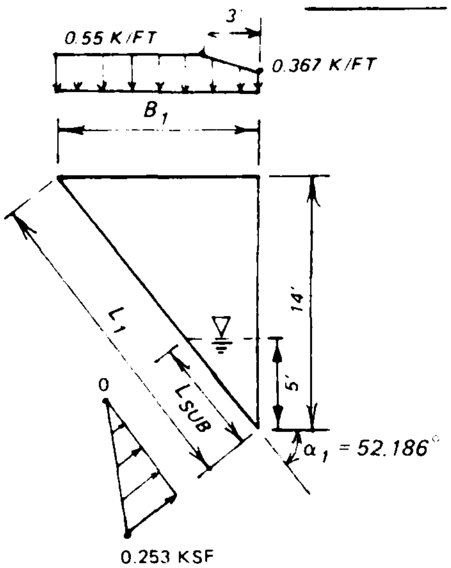
$$P_{toe} = 0.111 \text{ ksf}$$

(Continued)

(Sheet 1 of 4)

Hand Check (Continued)

Wedge 1



$$B_1 = \frac{14}{\tan \alpha_1} = 10.87'$$

$$L_1 = \frac{14}{\sin \alpha_1} = 17.72'$$

$$L_{sub} = \frac{5}{\sin \alpha_1} = 6.33'$$

$$\frac{\text{Total Ramp Load}}{\text{Total Ramp Length}} = \frac{(0.55 - 0)}{9'} = 0.0611 \ \frac{k/ft}{ft}$$

$$\begin{array}{l}\text{Surcharge at Right}\\ \text{End of Wedge 1}\end{array} = 0.0611 \times 6' = 0.367 \ k/ft$$

Vertical Loads, $V_1 = 0.55 \ k/ft(10.87' - 3') + \frac{1}{2}(0.55 + 0.367)(3') = 5.70^k$

$\text{Weight}_1 = \frac{1}{2}(14 \times 10.87)(0.120 \ kcf) = 9.13^k$

$\text{Uplift}_1 = \frac{1}{2}(0 + 0.253)(6.33') = 0.801^k$

Net force,

$$P_0 - P_1 = \frac{[(9.13 + 5.70)\cos \alpha_1 - 0.801]\dfrac{\tan \phi_1}{1.825} + (9.13 + 5.70)\sin \alpha_1}{\cos \alpha_1 - \sin \alpha_1 \left(\dfrac{\tan \phi_1}{1.825}\right)}$$

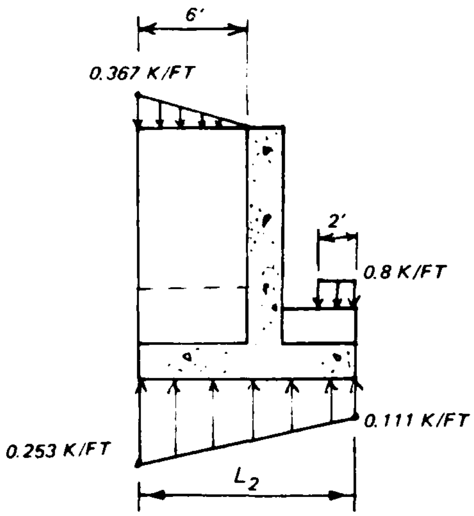
$$P_0 - P_1 = -11.03^k$$

(Continued)

(Sheet 2 of 4)

Hand Check (Continued)

Wedge 2



$$L_2 = L_{sub} = 12'$$

$$Weight_2 = 7.2^k \text{ see first hand calculation}$$

$$Uplift_2 = 2.184^k \text{ see first hand calculation}$$

$$V_2 = \text{soil} + \text{surcharges}$$

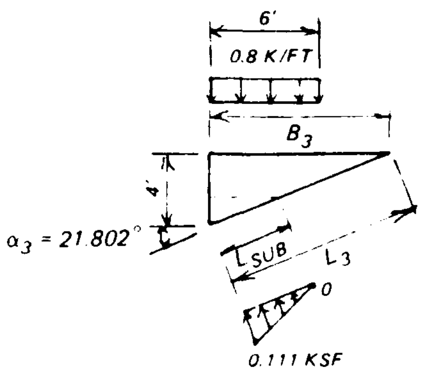
$$\text{soil} = 9.6^k$$

$$\text{surcharges} = \frac{1}{2}(0.367)(6') + 0.8(2') = 2.70$$

$$V_2 = 9.6^k + 2.70^k = 12.30^k$$

Net; $P_1 - P_2 = 5.48^k$

Wedge 3



$$B_3 = \frac{4'}{\tan \alpha_3} = 10.00'$$

$$L_3 = \frac{4'}{\sin \alpha_3} = 10.77'$$

$$L_{sub} = \frac{1.5'}{\sin \alpha_3} = 4.04'$$

$$V_3 = 0.8 \text{ k/ft } (6') = 4.8^k$$

$$W_3 = \frac{1}{2}(4 \times 10)(0.120 \text{ kcf}) = 2.40^k$$

$$U_3 = \frac{1}{2}(0.111)(4.04') = 0.224^k$$

Net force; $P_2 - P_3 = 5.55^k$

(Continued)

(Sheet 3 of 4)

Hand Check (Concluded)

The sum of net forces is:

$$\sum (P_{i-1} - P_i) = -11.03^k + 5.48^k + 5.55^k = 0.00^k$$

NOTE: The point load is not included in the surcharges since it lies just outside the passive wedge. CSLIDE chooses the angle producing a minimum passive force. To include the 2-kip load would only increase the passive resistance and produce a higher safety factor. The critical condition is the failure mechanism with the lowest safety factor.

(Sheet 4 of 4)

Table A2

Summary of Problem 1, Vertical Surcharges--CSLIDE and Hand Calculations

Wedge Number	Horizontal Loads: Left Side (kips) CSLIDE	Left Side Hand	Right Side (kips) CSLIDE	Right Side Hand	Vertical Load (kips) CSLIDE	Vertical Load Hand	Failure Angle (deg) CSLIDE	Failure Angle Hand
1	0.000	0.0	0.000	0.0	5.701	5.70	-52.186	-52.186
2	0.000	0.0	0.000	0.0	12.300	12.30	0.000	0.000
3	0.000	0.0	0.000	0.0	4.800	4.80	21.802	21.802

Wedge Number	Total Length (ft) CSLIDE	Total Length Hand	Weight of Wedge (kips) CSLIDE	Weight of Wedge Hand	Submerged Length (ft) CSLIDE	Submerged Length Hand	Uplift Force (kips) CSLIDE	Uplift Force Hand
1	17.722	17.72	9.127	9.13	6.329	6.33	0.802	0.801
2	12.000	12.00	7.200	7.20	12.000	12.00	2.189	2.184
3	10.770	10.77	2.400	2.40	4.039	4.04	0.225	0.224

Wedge Number	Net Force on Wedge (kips) CSLIDE	Net Force on Wedge Hand
1	-11.029	-11.03
2	5.475	5.48
3	5.554	5.55
Sum of Forces	0.000	0.00

FACTOR OF SAFETY = 1.825

Comments on Results

28. The safety factor for the system with loads is greater than the safety factor for the system without loads. In the loaded system, the passive force of wedge 3 is more than double the passive force in the unloaded system. The active force of the loaded wedge 1 increases by only 66 percent over the active force in the unloaded case. This accounts for the larger safety factor for the system with loads.

Problem 2

Summary

29. This example problem shows some CSLIDE capabilities and limitations in modeling various soil and structure configurations. The structure in this problem is a gravity dam with an irregular base shown in Figure A3a. In CSLIDE, the structure's base must be represented by only one plane of sliding. The structure model for CSLIDE is shown in Figure A3b. The left-side soil surface slopes down away from the structure. The right-side soil surface is at the base of the structure, therefore, no passive wedge exists.

30. The "RERU" command is used in the data file to edit data and rerun the program.

31. A second analysis in this example demonstrates how to:

a. Use earthquake acceleration coefficients and interpret the results.

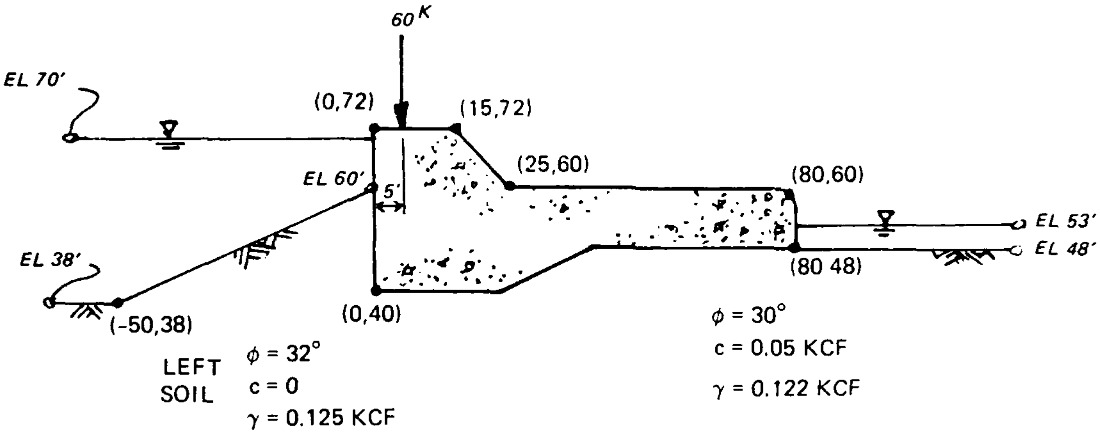
b. Input a specific failure plane and interpret the results.

Requirements

32. For this problem, the following are required:

a. Calculate the factor of safety against sliding of the dam shown in Figure A3a, using the model shown in A3b.

b. Calculate the factor of safety when the dam is under seismic conditions. Earthquake acceleration coefficients for the dam's location are: horizontal 0.07, vertical 0.02. Assume the failure mechanism for seismic conditions is the one shown in Figure A4.



a. Gravity dam with irregular base

b. Model of the irregular base for CSLIDE analysis

Figure A3. Problem 2 - gravity dam

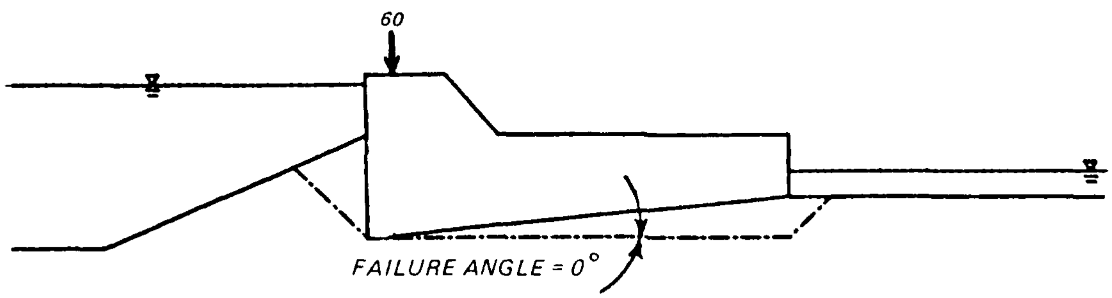


Figure A4. Failure mechanism for seismic conditions

33. The data for all requirements of Problem 2 are shown in the one data file below. Right-side soil data is required in the input, even though no wedge will be formed in the first analysis. Data is edited within the data file for a second analysis, using the keyword "RERU".

34. In CSLIDE, earthquake forces are not applied to water that is above the ground surface and/or on the structure. The user should enter a horizontal force on each wedge in order to have seismic water forces considered in the analysis (paragraph 85-text). Seismic force from water above ground can be calculated from Westerguard's* equation as $W_{EQ} = (2/3)C_E K_h h^2$, where K_h is the horizontal earthquake coefficient, h is the height of water, and C_E is a factor based on the depth of water:

$$C_E = \frac{0.051}{\sqrt{1 - 0.72\left(\frac{h}{1000\ T}\right)^2}}$$

where

T = earthquake foundation period of vibration
= 1 sec (avg)

For this example,

$$C_{E_{Left}} = \frac{0.051}{\sqrt{1 - 0.72\left(\frac{10\ ft}{1000(1\ sec)}\right)^2}} = 0.051^{k\text{-}sec\text{-}ft}$$

$$C_{E_{Right}} = \frac{0.051}{\sqrt{1 - 0.72\left(\frac{5\ ft}{1000(1\ sec)}\right)^2}} = 0.051^{k\text{-}sec\text{-}ft}$$

$$W_{E.Q._{Left}} = \frac{2}{3}\,(0.051)(0.07)(10')^2 = 0.238^k$$

$$W_{E.Q._{Right}} = \frac{2}{3}\,(0.051)(0.07)(5')^2 = 0.0595^k$$

$$\text{Total } W_{E.Q.} = 0.2975^k \text{ acting to the right}$$

---

* See paragraph 85.

This is a load added to the structural wedge as an external horizontal load. The command word "HOLO" is used in the data file.

Data File for Problem 2

```
100 TITL CSLIDE DAM -- PROBLEM 2
110 STRU 6 .15                      (IPT GAMC)
120 0 40 0 72 15 72
130 25 60 80 60 80 48               (Structure Coordinate Points)
140 SOLT 1 2 32 0 .125 60           (NLT LPTS PHIL COL GAML STELL)
150 -400 38 -50 38                  (Soil Layer Coordinate Points)
160 SOST 30 0.05                    (PHCC CCS)
170 SORT 1 1 30 .05 .122 48         (NRT RPTS PHIR COR GAMR STELR)
180 400 48                          (Soil Layer Coordinate Points)
190 METH 1                          (MEAN)
200 UPLO 5 60                       (XPLO PLO)
210 WATR 70 53 .0625                (WLL WLR GAMW)
220 END
230 RERU
235 HOLO 2 .2975                    (WEDN HLOAD)
240 EQAC 0.02 0.07                  (EQVT EQHO)
250 WEDG 2 0.0                      (IWEDGE FANG)
260 END
```

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER 'T' OR 'F'.
? F

 ENTER DATA FILE NAME (MAXIMUM 7 CHARACTERS)
? EQ2


INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? N

 DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
 TERMINAL, FILE, BOTH, OR NEITHER?
 ENTER 'T', 'F', 'B' OR 'N'
? N

 DO YOU WANT TO PLOT THE INPUT DATA.  ENTER 'Y' OR 'N'.
? N

DO YOU WISH TO CONTINUE SOLUTION?
ENTER 'Y' OR 'N'
? Y

 IS OUTPUT TO GO TO YOUR TERMINAL, A FILE,
 OR BOTH? ENTER 'T','F' OR 'B'
? T

DO YOU WANT TO PRINT TEMPORARY RESULTS?
ENTER 'Y' OR 'N'
? N
```

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/05/22. TIME: 08.39.28.

CSLIDE DAM -- PROBLEM 2

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	1.681	.000	3.820
2	3.125	.781	60.000
3	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.775	1.663

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.663
80.00	.313

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.000	.000

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-72.771	18.425	6.822	18.425	22.465
2	5.711	80.399	228.000	80.399	79.428
3	.000	.000	.000	.000	.000

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-34.412
2	34.412
3	.000

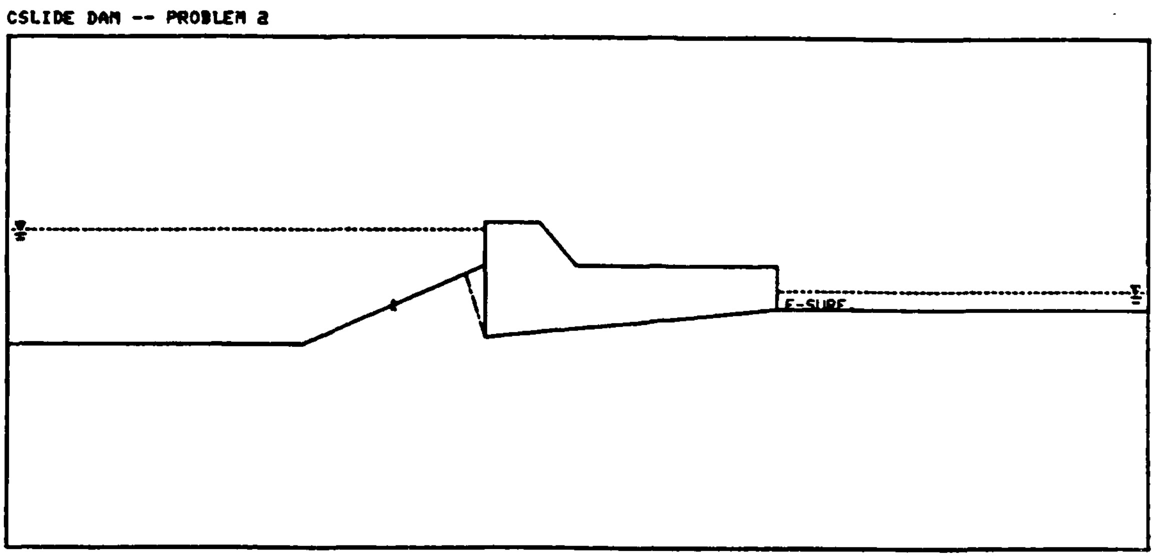
SUM OF FORCES ON SYSTEM ---- .000

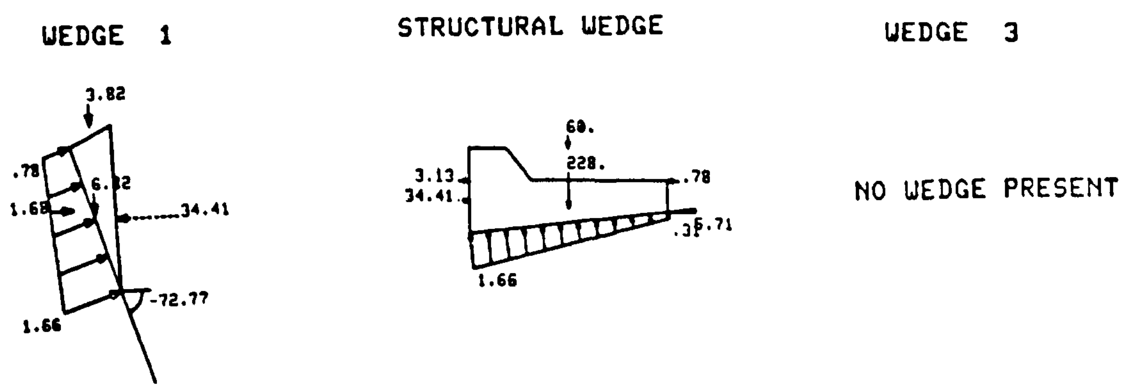
FACTOR OF SAFETY ----------- 15.882

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
? Y

35. The failure surface and wedge plots for Problem 2 are shown below.

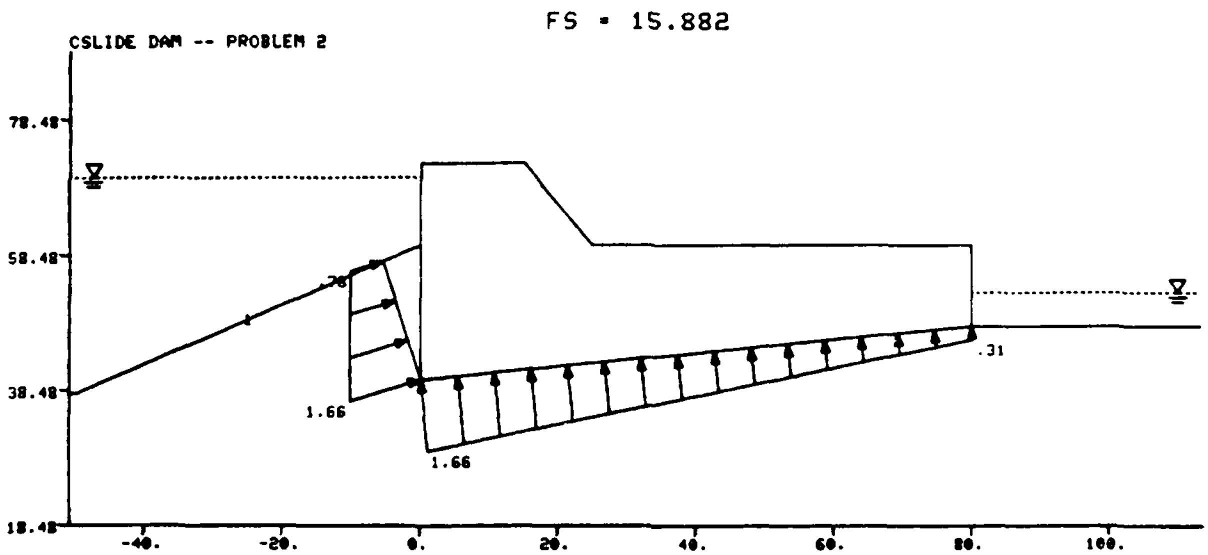
OUTPUT GRAPHICS





(Reduced Plots)

36. "W," "A," "O," then "R," are entered to Replot the picture with Water pressures shown on the wedges, Axes on the plot, and the plot Outline removed.



Plot of failure surface and water pressure on wedges

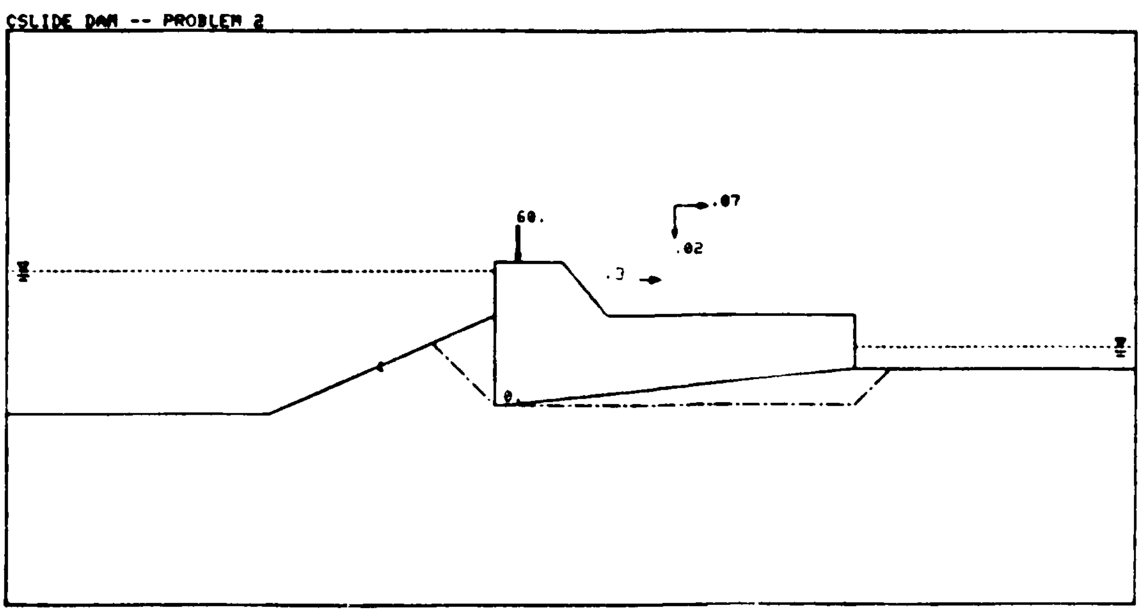
37. After the first analysis is complete, a message is given, as shown below, to indicate that the keyword "RERU" and new data have been read into the program, and a new analysis is to begin.

```
DO YOU WISH TO EDIT DATA AND RERUN PROBLEM?
(ENTER 'Y' OR 'N')
> N

 ***** MODIFIED PROBLEM ENTERED FROM FILE *****


INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
> N

 DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
 TERMINAL, FILE, BOTH, OR NEITHER?
 ENTER "T", "F", "B" OR "N"
> N
```

This message indicates that the keyword "RERU" and edited data were read into the program.

```
 DO YOU WANT TO PLOT THE INPUT DATA.  ENTER 'Y' OR 'N'.
? Y
```

38. A plot of modified input data is shown below as requested by the user.



Plot of input data for seismic conditions, paragraph 38, Problem 2

Output for Seismic Analysis

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/05/22. TIME: 08.42.50.

CSLIDE DAM -- PROBLEM 2

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	4.309	.000	8.026
2	26.315	.781	105.581
3	.474	.000	4.474

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.904	1.678

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.678
80.00	.891

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.313	.891

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-56.797	18.558	12.703	18.558	23.965
2	.000	80.000	228.000	80.000	102.778
3	29.950	16.024	6.775	16.024	9.644

INPUT STRUCTURAL ANGLE, EXTENDED, INTERSECTS
BELOW THE SIDE OF THE STRUCTURAL WEDGE AT
------------------------- (80.00, 40.00)

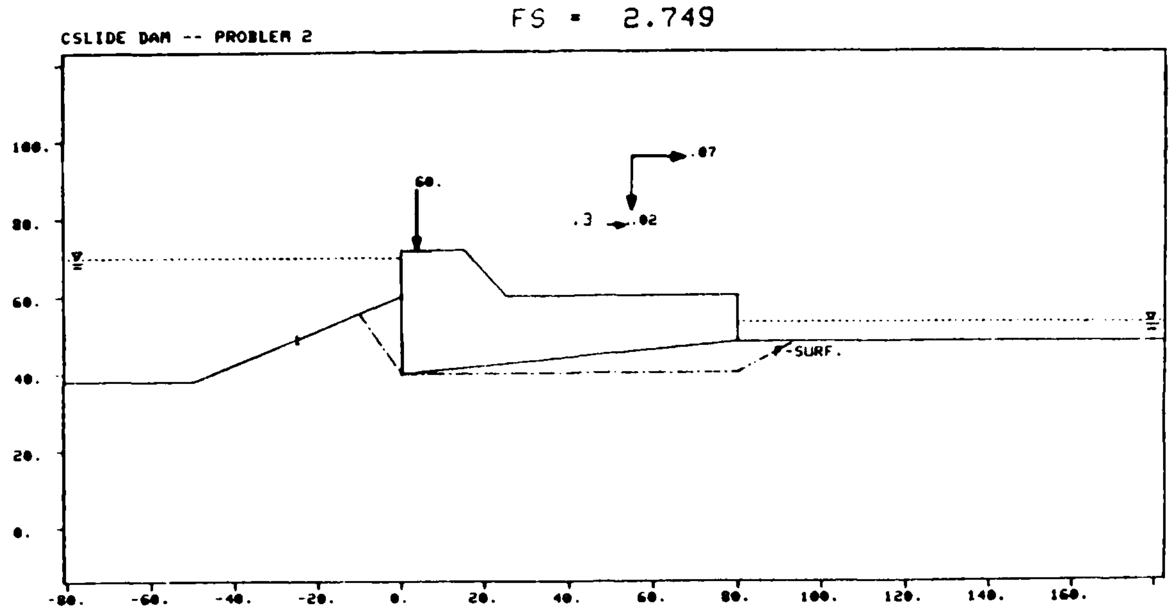
Coordinate point at which the third wedge begins. (See the output plot)

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-31.704
2	24.393
3	7.311

SUM OF FORCES ON SYSTEM ---- .000

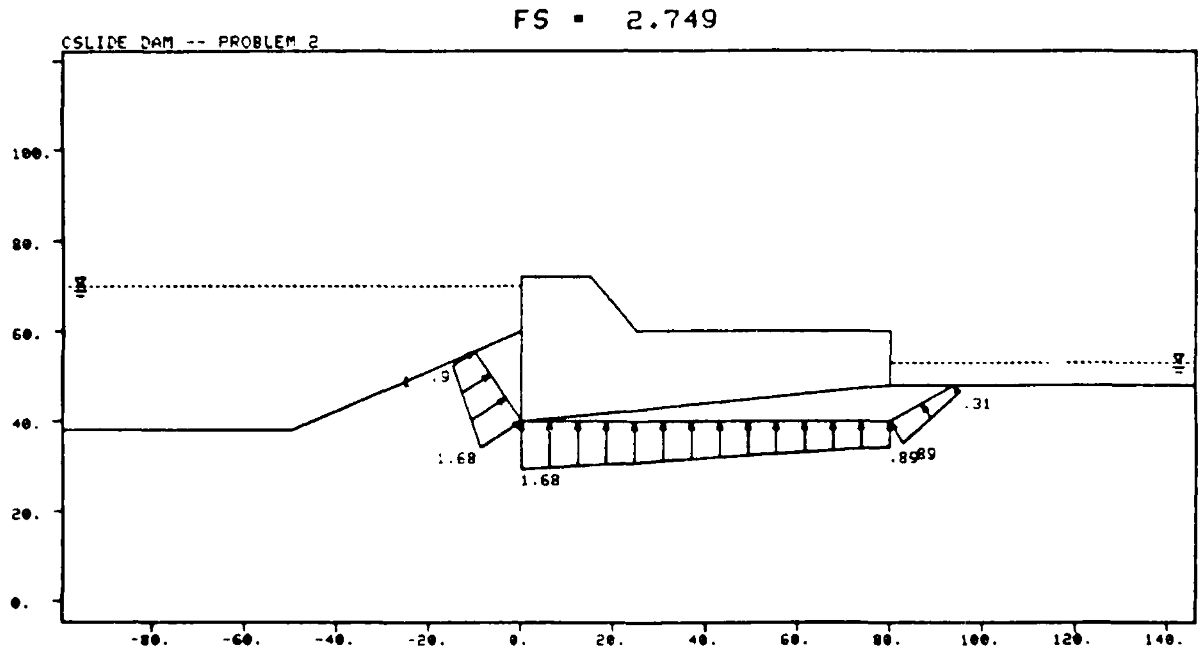
FACTOR OF SAFETY ----------- 2.749

39. Due to the earthquake loading, there is a large safety factor decrease from the first analysis. The message shown in the output [illegible] the coordinate point at which the failure plane of Wedge 3 begins. This can be seen in the output plots which follow.



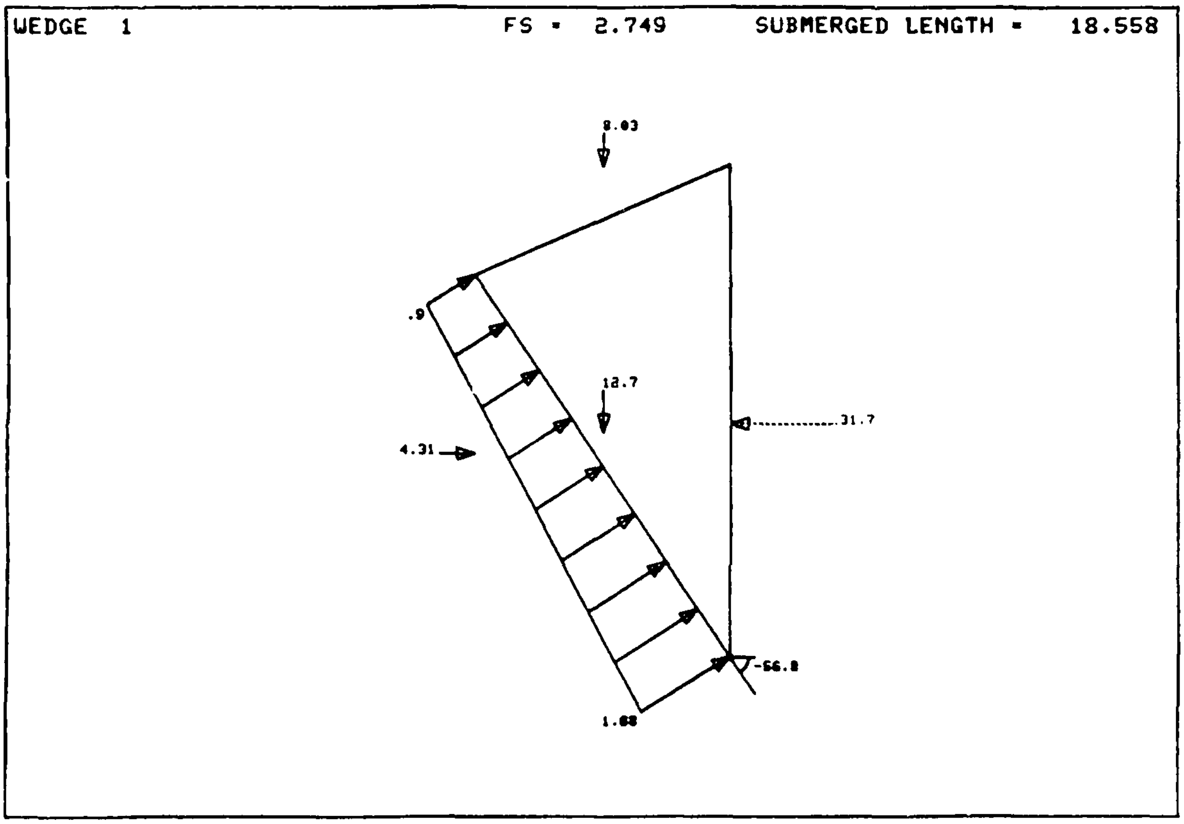
Failure surface under seismic conditions

"A"xis and "P"ick-a-window commands have been chosen for this plot.

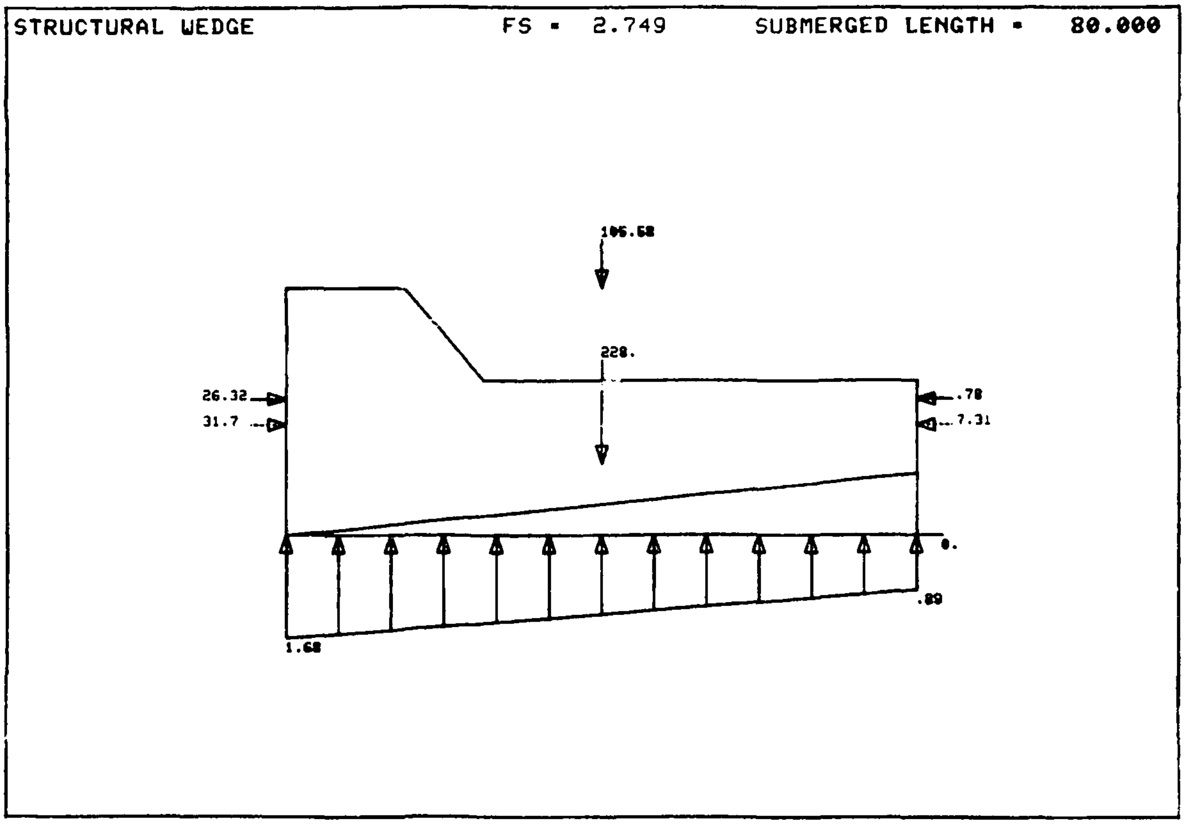


40. The "W" command was entered for this replotting of the failure surface to show water pressures on the wedges. The individual wedges are shown in the following plots.

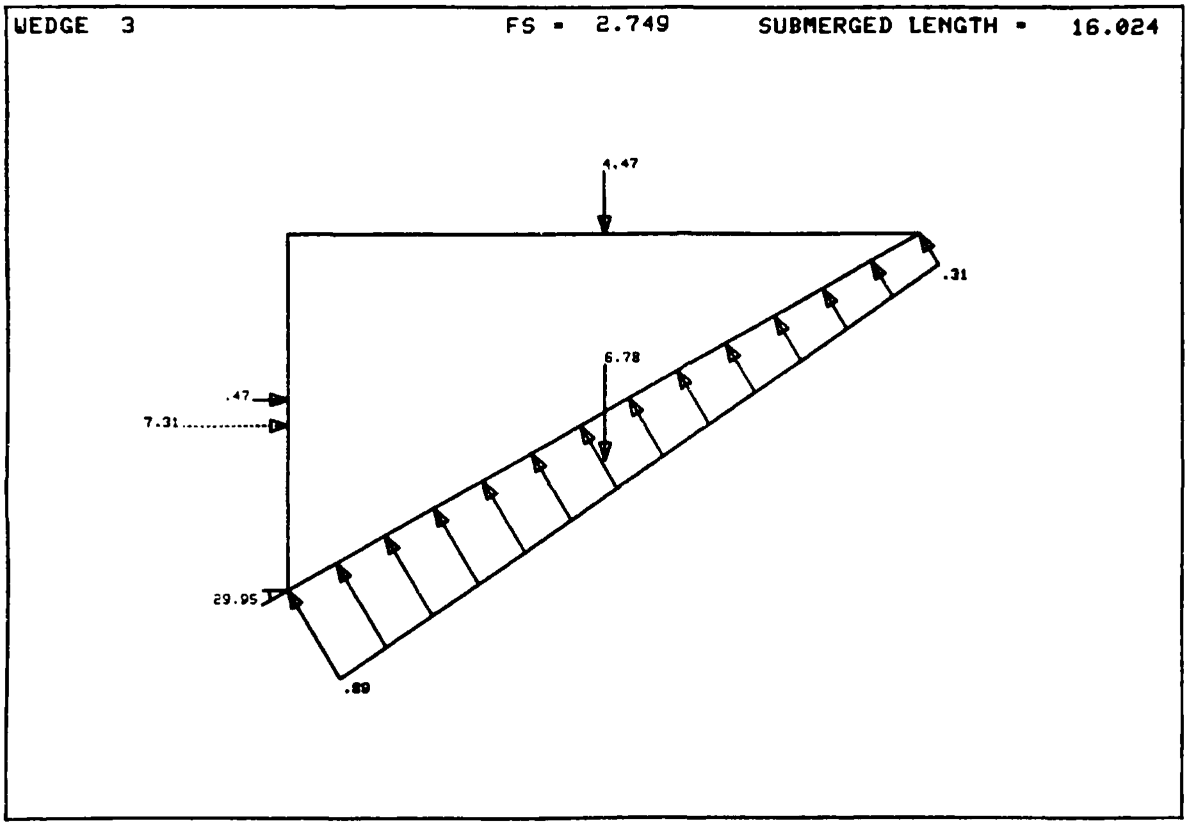
CSLIDE DAM -- PROBLEM 2



CSLIDE DAM -- PROBLEM 2



CSLIDE DAM -- PROBLEM 2



41. The calculation of vertical and horizontal loads when earthquake conditions are used as follows:

Vertical earthquake load = Vertical earthquake coefficient
X (total weight of wedge
+ external vertical loads other than water)

Horizontal earthquake load = Horizontal earthquake coefficient
X (total weight of wedge
+ external vertical loads other than water)

Any water load on top of the wedge is <u>not</u> included in these calculations.

42. The resultant loads on each wedge, shown in the CSLIDE output, are composed of several individual loads described below:

V_{total} = vertical earthquake load + external vertical loads + vertical water load

$H_{left\ total}$ = positive (direction) external horizontal loads + left-side horizontal water load

$H_{right\ total}$ = negative (direction) external horizontal loads + right-side horizontal water load

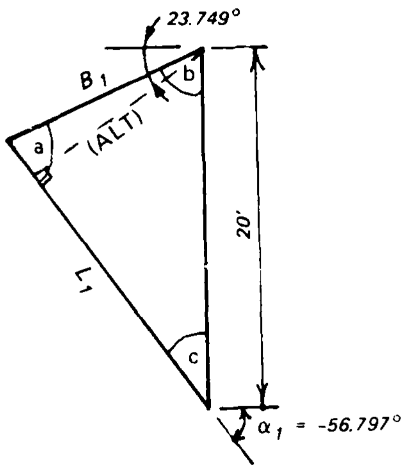
The horizontal earthquake load is added to H_{left} if EQHO is positive. It is added to H_{right} if EQHO is negative.

43. On the following pages are shown the hand-checked computations for this part of Problem 2.

Hand Check--Problem 2, Earthquake Conditions

Computations for External Loads Only

Wedge 1



Angles:

$c = 33.203°$

$b = 66.251°$

$a = 80.546°$

$$\frac{\sin c}{B_1} = \frac{\sin a}{20} = \frac{\sin b}{L_1} \quad \therefore \quad L_1 = 18.558'$$

$$B_1 = 11.103'$$

$$\text{altitude} = R = (\sin c)(20') = 10.952'$$

$$\text{Weight, } W_1 = \frac{1}{2}(R)(L_1)(0.125 \text{ kcf}) = 12.703^k$$

$$EQ_V = 0.02(W_1) = 0.254^k$$

$$EQ_H = 0.07(W_1) = 0.889^k$$

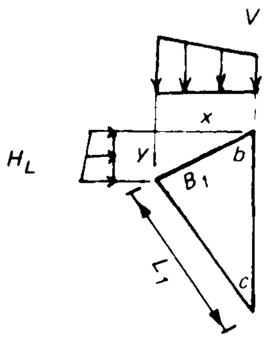
(Continued)

(Sheet 1 of 3)

Hand Check (Continued)

Wedge 1 (Continued)

Water Loads (External)



$x = (\sin c)\ L_1 = 10.162'$

$y = (\cos b)\ B_1 = 4.472'$

Water loads, $V = \frac{1}{2}\ [(10 + 4.47)\text{ksf} + 10\text{ ksf})]\gamma_w(10.162')$

$= 7.771^k$

$H_L = \frac{1}{2}\ (14.47 + 10)\text{ksf}\ \gamma_w(4.47')$

$= 3.420^k$

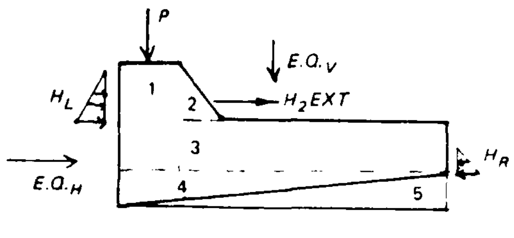
Totals:

$V_1 = V_w + EQ_V = 7.771^k + 0.254^k = 8.025^k$

$H_{L_1} = H_L + EQ_H = 3.420^k + 0.889^k = 4.309^k$

$H_{R_1} = 0$

Wedge 2 - Structure



$15' \times 24' = 360\ ft^2$

$\frac{1}{2}\ (10' \times 12') = 60\ ft^2$

$65' \times 12' = 780\ ft^2$

$\frac{1}{2}\ (80' \times 8') = 320\ ft^2$

Total Area $1520\ ft^2 \times 0.15\text{ kcf} \times 1'$

Weight, $W_2 = 228.0^k$

Soil $= \frac{1}{2}\ (80' \times 8') = 320\ ft^2$

Weight, $W_{soil} = 320\ ft^2\ (0.122\text{ kcf})(1\text{ ft})$

$= 39.040^k$

(Continued)

(Sheet 2 of 3)

Ha[illegible] Check (Concluded)

Wedge 2 (Continued)

$$V = 60^k \text{ (point load)}$$

$$EQ_V = 0.02(W_2 + \text{soil} + V) = 6.541^k$$

$$EQ_H = 0.07(W_2 + \text{soil} + V) = 22.893^k$$

$$H_L = 10\ \gamma_w\left(\frac{1}{2}\right)(10') = 3.125^k$$

$$H_R = 5\ \gamma_w\left(\frac{1}{2}\right)(5') = 0.781^k$$

$H_2 = 0.2975^k$ (earthquake acceleration force of water. See para 34)

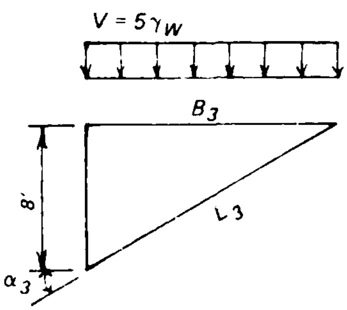
Total Loads:

$$V_2 = V + \text{soil} + EQ_V = 60 + 39.04 + 6.54 = 105.581^k$$

$$H_{L_2} = H_L + EQ_H + H_2 = 3.125 + 22.89 + 0.2975 = 26.316^k$$

$$H_{R_2} = H_R = 0.781^k$$

Wedge 3



$$B_3 = \frac{8'}{\tan \alpha_3} = 13.884'$$

$$L_3 = \frac{8'}{\sin \alpha_3} = 16.024'$$

$$\text{Weight, } W_3 = \frac{1}{2}(B_3 \times 8')(0.122\ \text{kcf}) = 6.775^k$$

$$EQ_V = 0.02(W_3) = 0.136^k$$

$$EQ_H = 0.07(W_3) = 0.474^k$$

$$V = 5'\ \gamma_w(B_3) = 4.339^k$$

Total Loads:

$$V_3 = V + EQ_V = 4.339 + 0.136 = 4.475^k$$

$$H_{L_3} = EQ_H = 0.474^k$$

$$H_{R_3} = 0$$

(Sheet [illegible] of [illegible])

Table A3

Summary of Problem 2--External Loads and Earthquake Conditions

CSLIDE and Hand Calculations

Wedge No.	Horizontal Loads: Left (kips) CSLIDE	Horizontal Loads: Left (kips) Hand	Horizontal Loads: Right (kips) CSLIDE	Horizontal Loads: Right (kips) Hand	Vertical Loads (kips) CSLIDE	Vertical Loads (kips) Hand
1	4.309	4.309	0.000	0.000	8.026	8.025
2	26.315	26.316	0.781	0.781	105.581	105.581
3	0.474	0.474	0.000	0.000	4.474	4.475

Problem 3

Summary

44. The purpose of this example is to demonstrate a way the user can control the failure mechanism in CSLIDE. A structure on a rock ledge is analyzed for sliding stability when the failure plane (a) passes around the rock and (b) passes through the rock. The latter case is found to produce a lower safety factor than the former.

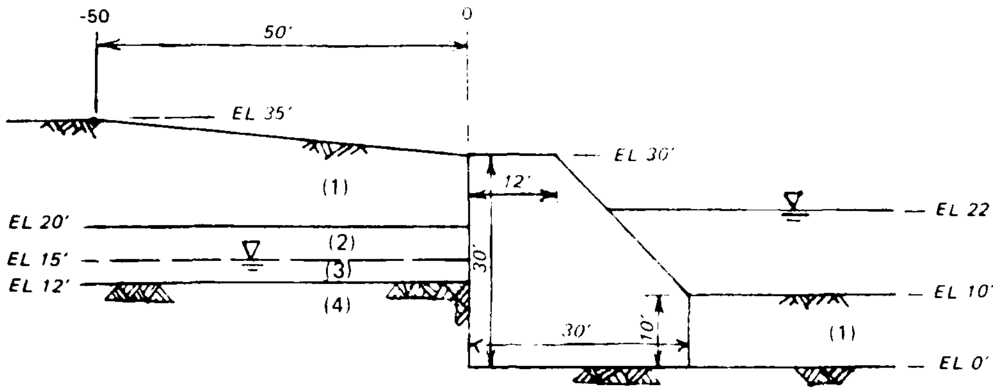
45. This example also shows that the water elevation on the passive side of the system may be higher than that on the active side. Seepage pressures are distributed from right to left in this case. A hand check of seepage calculations follows the final results.

Requirements

46. For this problem, the following items are required:

a. Determine the sliding factor of safety for the system shown in Figure A5. Assume that the rock is strong in shear relative to the soil, and check the failure plane which passes around the rock ledge on the left side of the structure, as shown in Figure A6a. An external horizontal load should be added to the structural wedge to account for the water force on the structure below the elevation of the lowest leftside wedge.

b. Determine the sliding factor of safety for the analysis which includes the rock on the left side in the failure mechanism, as in Figure A6b.



LEFT SOIL

(1) FILL, γ = 108 PCF
ϕ = 30°
c = 0

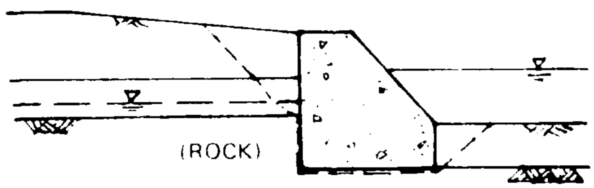
(2) & (3) FILL,
γ_m = 95 PCF
γ_{sat} = 118 PCF
ϕ = 31°
c = 0

(4) ROCK, γ = 168 PCF
ϕ = 38°
c = 200 PCF

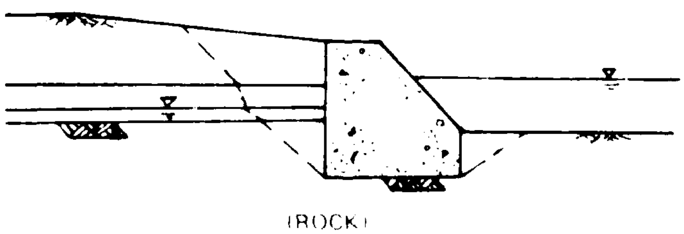
RIGHT SOIL

(1) FILL, γ = 115 PCF
ϕ = 32°
c = 0

Figure A5. Soil and structure description



a. Failure mechanism around the rock



b. Failure mechanism through the rock ledge

Figure A6. Models for Problem 3 analyses

47. In the data file for the first analysis, paragraph 44a, only the top three left soil layers are entered. This file is printed below. Following this data file is the plot of input data.

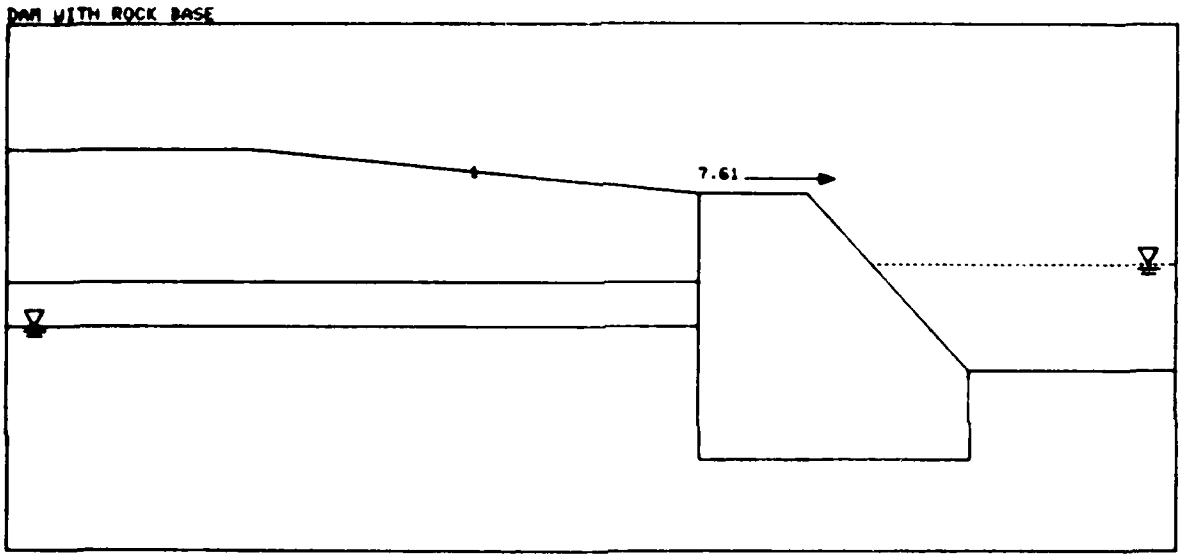
Data File for Problem 3 (Figure A6a)

"ANEL" - failure angle elevation at the structure = 12 ft

"HOLO" - external horizontal load of water on left side of structure, below ANEL

```
00100 TITL DAM WITH ROCK BASE
00110 STRU 5 .15 12             (IPT GAMC ANEL)
00120 0 0 0 30 12 30 30 10 30 0 Structure Coordinate Points
00130 SOLT 1 2 30 0 .108 30     (NLT LPTS PHIL COL GAML STELL)
00140 -500 35 -50 35            Soil Layer Coordinates
00150 SOLT 2 1 31 0 .095 20     (NLT LPTS PHIL COL GAML STELL)
00160 -500 20                   Soil Layer Coordinate
00170 SOLT 3 1 31 0 .118 15     (NLT LPTS PHIL COL GAML STELL)
00180 -500 15                   Soil Layer Coordinate
00190 SOST 38 .2                (PHIC CCS)
00200 SORT 1 1 32 0 .115 10     (NRT RPTS PHIR COR GAMR STELR)
00210 200 10                    Soil Layer Coordinate
00220 METH 2                    (MEAN)
00230 WATR 15 22 .0625 -1       (WLL WLR GAMW S)
00231 HOLO 4 7.608              (WEDN HLOAD)
00240 END
```

'ANEL' - failure angle elevation at the structure



Plot of input data

[illegible]8. Printed below are final results and plots of the analysis in which the failure plane goes around the rock.

PROGRAM CSLIDE - FINAL RESULTS

DATE: 87/07/15. TIME: 14.36.07.

DAM WITH ROCK BASE

MULTIPLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	.000
4	7.608	4.500	4.050
5	.000	.000	8.043

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.000
2	.000	.000
3	.000	.211

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.0[illegible]
30.00	1.295

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
5	.750	1.295

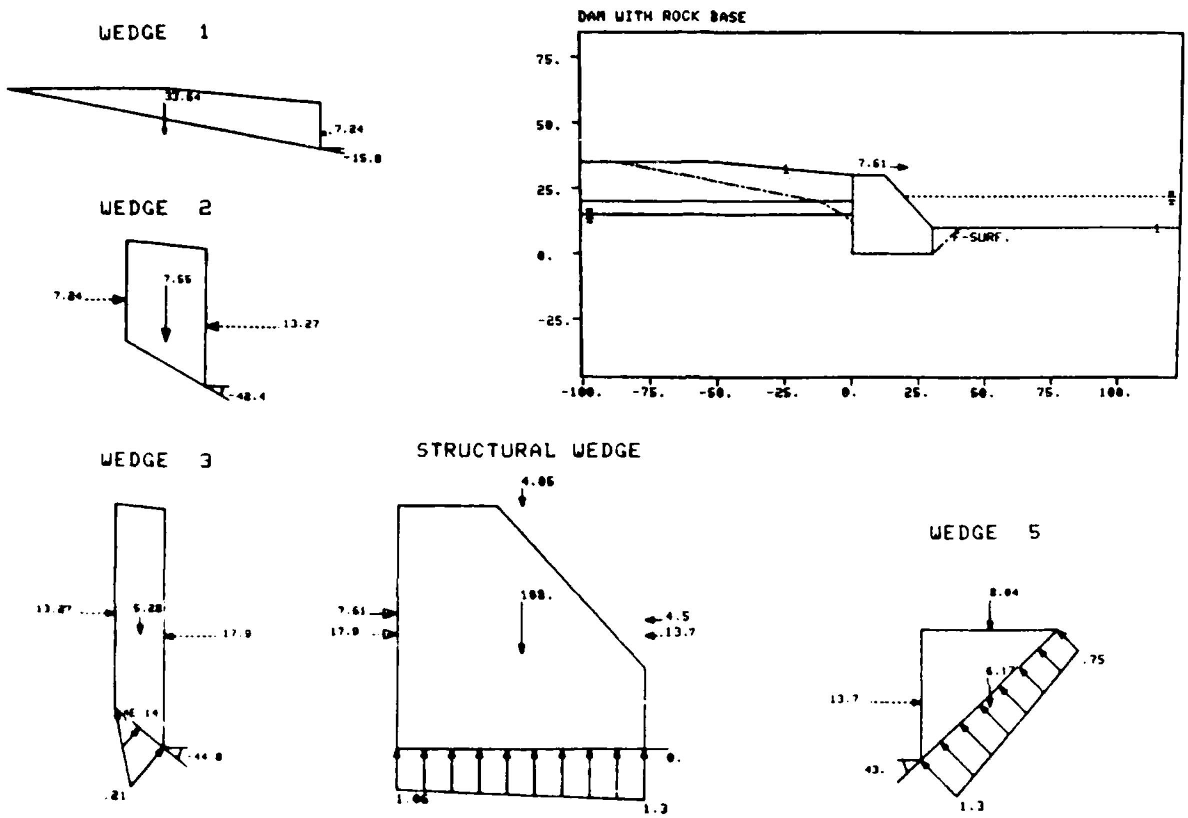
WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-15.8	55.090	33.636	.000	.000
2	-42.4	7.415	7.555	.000	.000
3	-44.8	4.258	5.282	4.258	.450
4	.000	30.000	108.000	30.000	35.284
5	43.0	14.663	6.166	14.663	14.996

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-7.236
2	-6.029
3	-4.630
4	4.198
5	13.698

SUM OF FORCES ON SYSTEM ---- .001

FACTOR OF SAFETY ----------- 9.030

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
?



Plots of the failure surface and wedges, paragraph 44a

49. On this and the following four pages are the data file for the second analysis of Problem 3, paragraph 44b, the plot of input data, the final results, and plots of the failure surface and wedges.

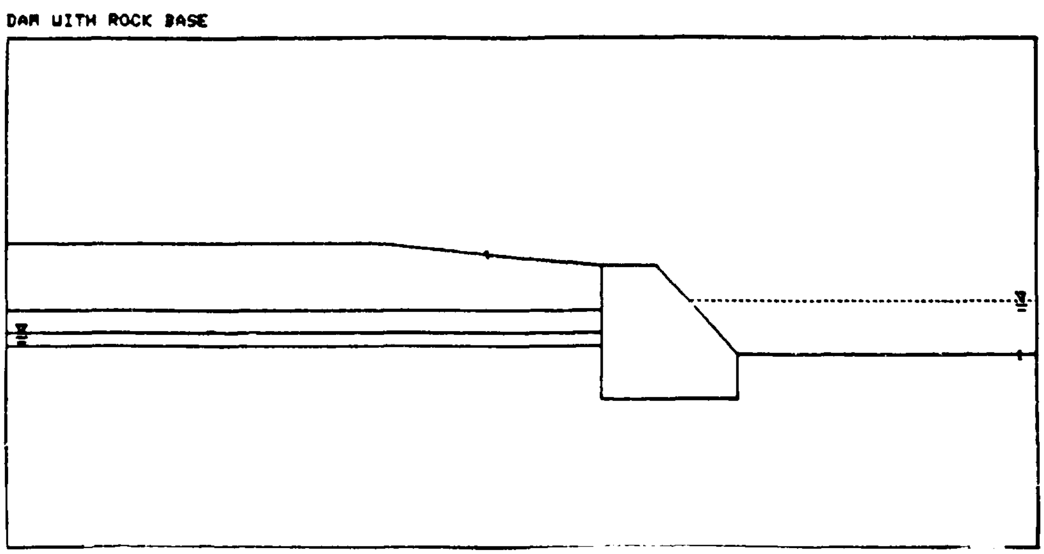
Data File for Problem 3 (Figure A6)

Failure surface through rock

Remove ANEL and HOLO from the data file of part 1.

Add a 4th left soil layer to describe the rock properties. (lines 00195–00196)

```
00100 TITL DAM WITH ROCK BASE
00110 STRU 5  .15
00120 0 0  0 30  12 30
00130 30 10  30 0
00140 SOLT 1 2 30 0 .108 30
00150 -500 35 -50 35
00160 SOLT 2 1 31 0 .095 20
00170 -500 20
00180 SOLT 3 1 31 0 .118 15
00190 -500 15
00195 SOLT 4 1 38 .2 .168 12
00196 -500 12
00200 SOST 38 .2
00210 SORT 1 1 32 0 .115 10
00220 200 10
00230 METH 2
00240 WATR 15 22 .0625 -1
00250 END
```



Plot of input data

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/05/23. TIME: 14.57.55.

DAM WITH ROCK BASE

MULTIPLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	.000
4	.000	.000	.000
5	.000	4.500	4.050
6	.000	.000	9.034

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.000
2	.000	.000
3	.000	.211
4	.211	1.057

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.057
30.00	1.295

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
6	.750	1.295

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-39.9	20.691	10.016	.900	.000
2	-48.9	6.635	6.438	.000	.000
3	-49.5	3.945	4.748	3.945	.417
4	-50.4	15.574	29.490	15.574	9.875
5	.000	30.000	108.000	30.000	35.284
6	39.7	15.655	6.926	15.655	16.011

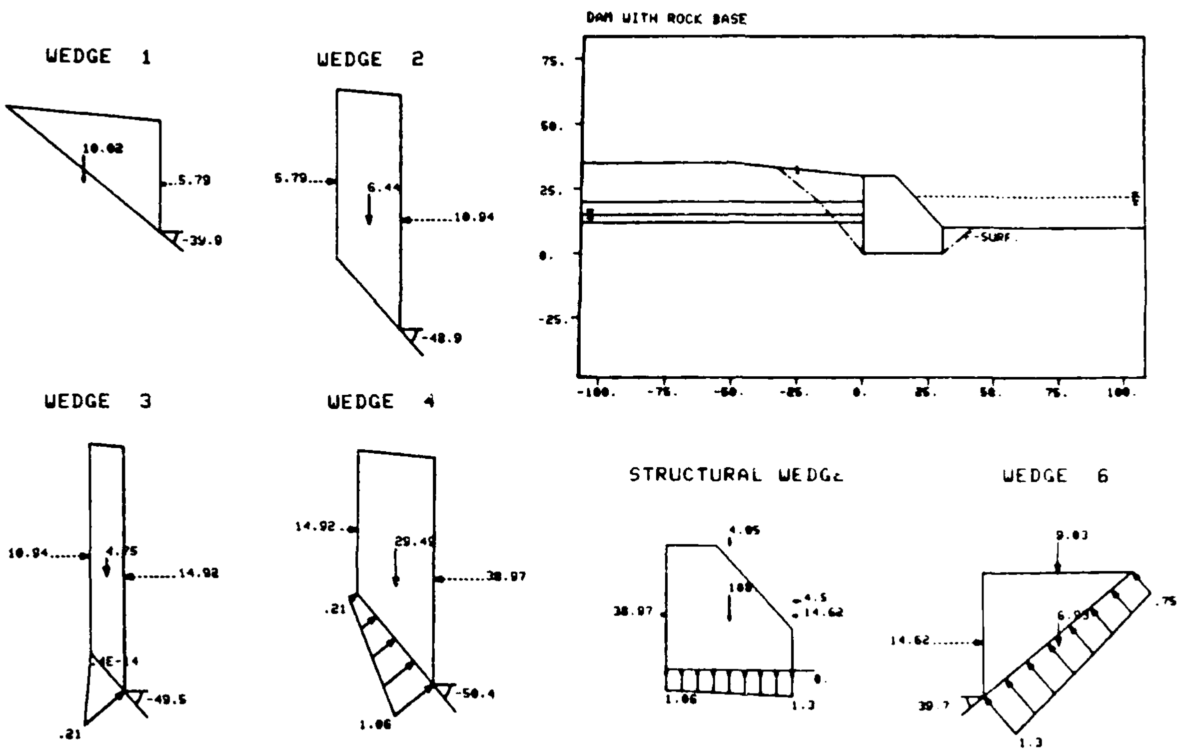
WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-5.794
2	-5.149
3	-3.975
4	-24.052
5	24.350
6	14.620

SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 3.324

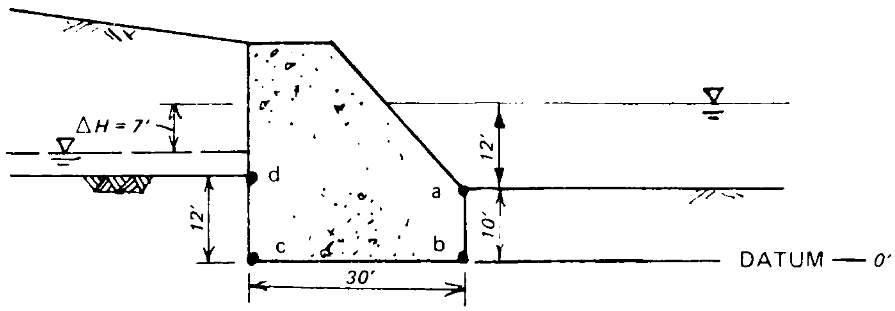
DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
?

50. The decrease in the safety factor results from the increase in the driving force. This increase was caused by including the rock in the failure mechanism.



Plot of failure surface and wedges, paragraph 44b

Hand Check--Problem 3, Seepage Calculations for "Reversed" Flow (Passive to Active Side)



"Line-of-Creep"

$$\text{Seepage gradient, } i = \frac{\Delta H}{L} = \frac{22' - 15'}{(10' + 30' + 15')} = 0.127273$$

$$\text{Pressure} = \begin{pmatrix}\text{unit}\\ \text{weight}\\ \text{water}\end{pmatrix}\left[\begin{pmatrix}\text{headwater}\\ \text{elevation}\end{pmatrix} - \begin{pmatrix}\text{point}\\ \text{elevation}\end{pmatrix} - (\text{gradient})\begin{pmatrix}\text{path}\\ \text{length}\end{pmatrix}\right]$$

$P_a = \gamma_w\ [22' - 10' - i(0)] =$ 0.750 ksf

$P_b = \gamma_w\ [22' - 0' - i(10')] =$ 1.295 ksf

$P_c = \gamma_w\ [22' - 0' - i(10' + 30')] =$ 1.057 ksf

$P_d = \gamma_w\ [22' - 12' - i(10' + 30' + 12')] =$ 0.211 ksf

These hand calculations match CSLIDE calculations.

See output.

Problem 4

Summary

51. This example problem demonstrates how one may enter precalculated seepage pressures into a CSLIDE analysis. The CSLIDE solution uses these input pressures instead of those calculated by one of the methods within the program. For instance, one may wish to use results obtained from a flownet or a finite element seepage analysis in the sliding stability analysis.

52. The dam to be analyzed for sliding safety if shown in Figure A7. As in Problem 2, the irregular base is modeled as a single plane. For simplicity, the joint between the dam and the spillway is ignored and the structure is treated as a unit in sliding. The analysis model is shown in Figure A8. The data file for this problem is one long file containing three separate analyses. This shows the use of the command word "RERU" for editing from within a file to rerun the problem, and the command word "NEW" for entering a new set of data.

Requirements

53. For this problem, the following are required:

a. Find the sliding factor of safety of the dam shown in Figure A7 using the water pressures acting on the wedge vertices and structure base. These pressures are obtained from the flownet shown in Figure A7.

b. Analyze the dam of paragraph 51a a second time, using water pressures calculated by CSLIDE from the line-of-creep method of analysis.

c. Determine the FS of a smaller dam located upstream of the first one. This dam is shown in Figure A9. Use just one data file for all three parts of this problem.

54. The structure's base is modeled as a single plane, however, water pressures are calculated along the actual base configuration, shown in Figure A7. All pressure calculations are shown below.

$$\text{Pressure} = \gamma_w \left(\begin{matrix}\text{Tailwater} \\ \text{elevation}\end{matrix} - \begin{matrix}\text{Elevation of} \\ \text{point of interest}\end{matrix} + \text{\% of } \Delta H \text{ remaining} \right)$$

Wedge 1:

$$P_a = (100\%\ \Delta H) = [64' - 50' + 1.0(31')]\gamma_w$$
$$= 2.813 \text{ ksf}$$

$$P_b = (77\%\ \Delta H) = [64' - 0' + 0.77(31')]\gamma_w$$
$$= 5.492 \text{ ksf}$$

Wedge 2:

$$P_b = 5.492 \text{ ksf}$$

$$P_c = (33\%\ \Delta H) = [64' - 14' + 0.33(31')]\gamma_w$$
$$= 3.764 \text{ ksf}$$

$$P_d = (10\%\ \Delta H) = [64' - 14' + 0.10(31')]\gamma_w$$
$$= 3.319 \text{ ksf}$$

Wedge 3:

$$P_d = 3.319 \text{ ksf}$$

$$P_e = (0\%\ \Delta H) = [64' - 24' + 0]\gamma_w$$
$$= 2.50 \text{ ksf}$$

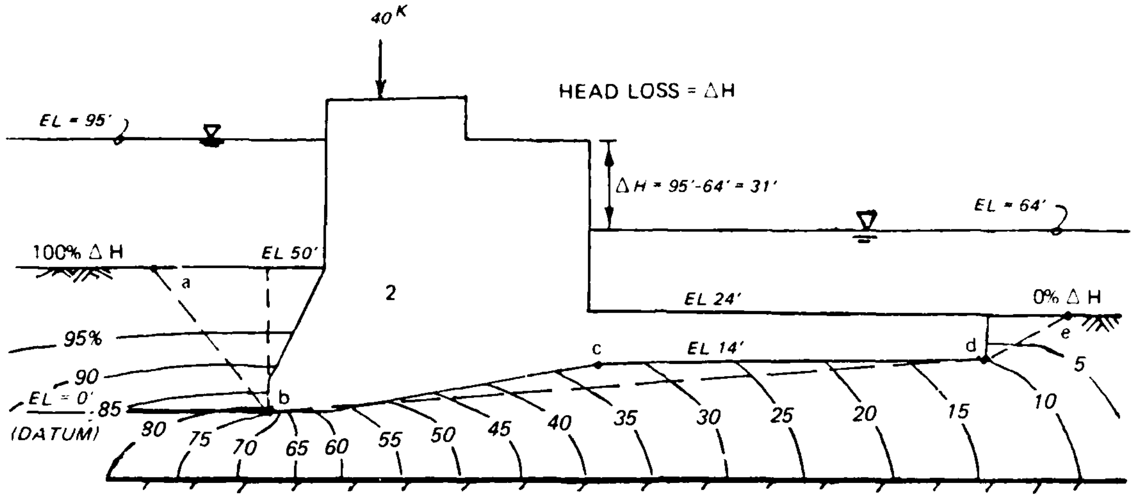


Figure A7. Equipotential lines (in percent head loss remaining)

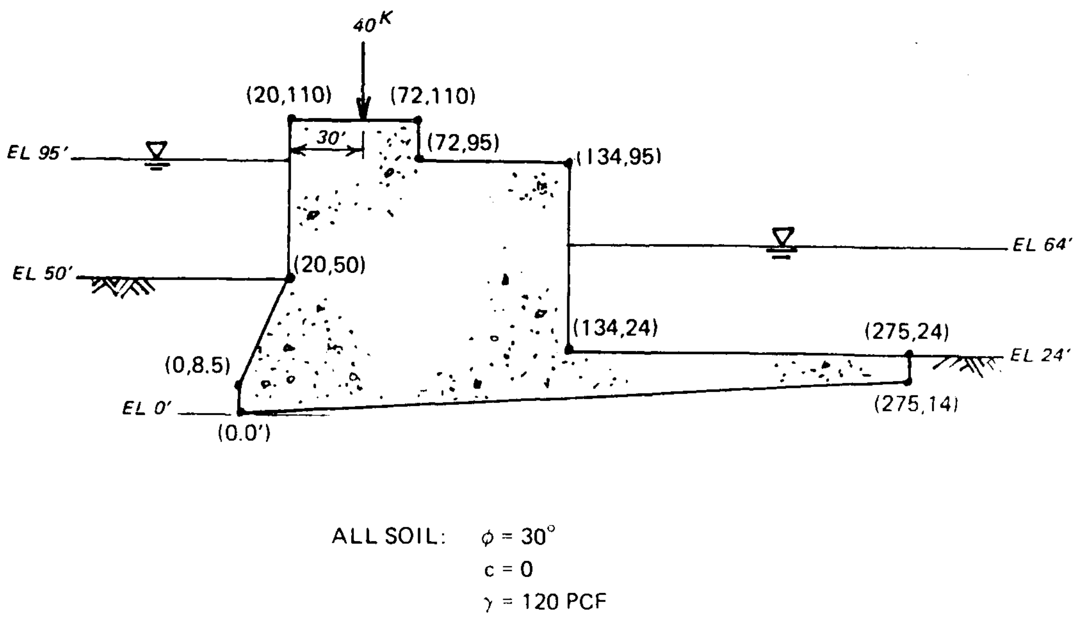
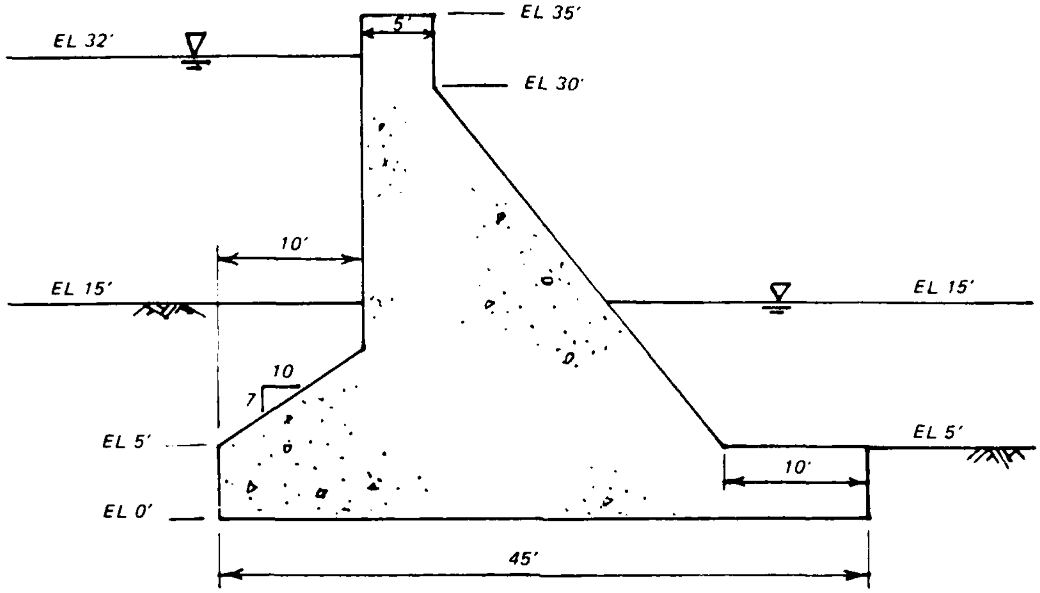


Figure A8. Soil and structure model for Problem 4, paragraphs 51a and b, with structure coordinate points shown, in feet



LEFT SOIL	RIGHT AND SUB-SOIL
$\phi = 30°$	$\phi = 34°$
c = 0	c = 40 PSF
γ = 115 PCF	γ = 126 PCF

Figure A9. Second dam to be analyzed in Problem 4, paragraph 51c

55. The data file for Problem 4 contains three separate analyses and is printed below.

Data File for Problem 4

Dam with input pressures

```
00100 TITL DAM NO.4
00110 STRU 10 .15
00120 0 0 0 8.5 20 50 20 110 72 110
00130 72 95 134 95 134 24 275 24 275 14
00140 SOLT 1 1 30 0 .12 50
00150 -100 50
00160 SOST 30 0
00170 SORT 1 1 30 0 .12 24
00180 400 24
00190 METH 1
00200 WATR 95 64 .0625 1
00210 2.813 5.492
00220 3
00230 0 5.492
00240 134 3.764
00250 275 3.319
00260 2.5 3.319
00270 VPLO 50 40
00280 END
```

Line-of-creep seepage

```
00290 RERU
00300 TITL LINE-OF-CREEP SEEPAGE
00310 WATR 95 64 .0625 -1
00320 END
00330 NEW
```

Data for 2nd dam

```
00340 TITL UPSTREAM DAM NO. 4A
00350 STRU 9 .15
00360 0 0 0 5 10 12 10 35 15 35
00370 15 30 35 5 45 5 45 0
00380 SOLT 1 1 30 0 .115 15
00390 -100 15
00400 SOST 34 .04
00410 SORT 1 1 34 .04 .126 5
00420 150 5
00430 WATR 32 15 .0625
00440 METH 2
00450 END
```

56. The echoprint and plot of input data for Problem 4, paragraph 51a, are on the following pages.

```
------------------------------
 PROGRAM CSLIDE - ECHOPRINT
------------------------------

DATE:  86/05/29.                        TIME:  15.30.16.

DAM NO.4

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED FROM INPUT PRESSURES.

NO OF CORNERS IN STRUCTURE ----------        10
DENSITY OF CONCRETE -----------------     .1500(KCF)
DENSITY OF WATER --------------------     .0625(KCF)
WATER LEVEL LEFT SIDE ---------------    95.00(FT)
WATER LEVEL RIGHT SIDE --------------    64.00(FT)
NO. OF SOIL LAYERS LEFT SIDE --------        1
NO. OF SOIL LAYERS RIGHT SIDE -------        1


STRUCTURE INFORMATION
---------------------
POINT          X-COORD        Y-COORD
-----          -------        -------

   1              .00            .00
   2              .00           8.50
   3            20.00          50.00
   4            20.00         110.00
   5            72.00         110.00
   6            72.00          95.00
   7           134.00          95.00
   8           134.00          24.00
   9           275.00          24.00
  10           275.00          14.00
```

LEFTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.120	50.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	-100.00	50.00

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 30.00
COHESION --------------- .0000

RIGHTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.120	24.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	400.00	24.00

INPUT PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	2.813	5.492

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	5.492
134.00	3.764
275.00	3.319

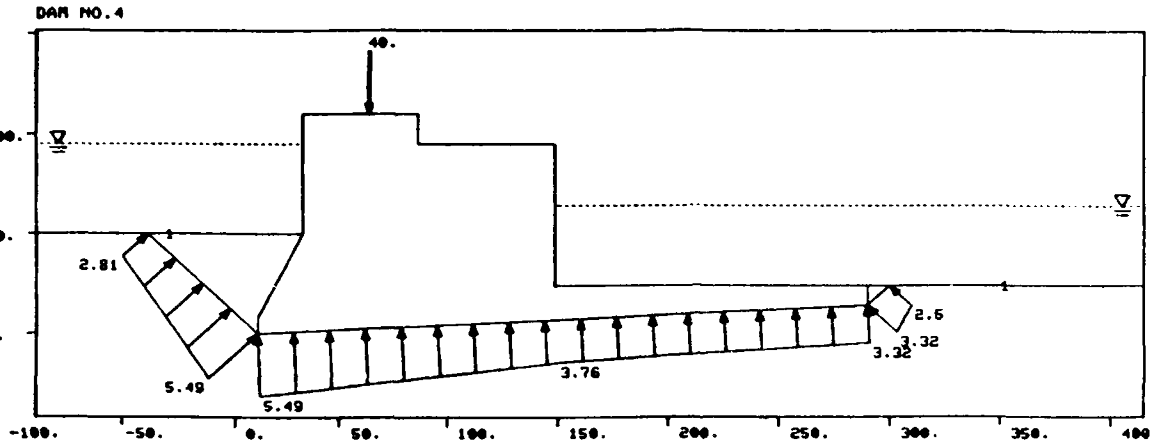
RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	2.500	3.319

VERTICAL POINT LOADS

X-COORDINATE (FT)	MAGNITUDE (KIPS)
50.00	40.000

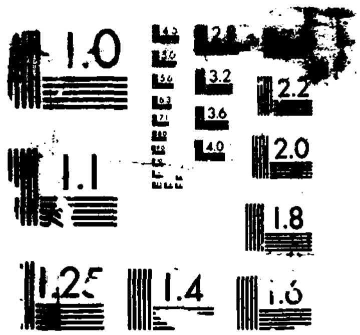
DO YOU WANT TO PLOT THE INPUT DATA. ENTER 'Y' OR 'N'.
?Y



Plot of input data, paragraph 51a

AD-A189 334 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT 3/4
SLIDING STABILITY OF..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS INFOR..

UNCLASSIFIED M E PACE ET AL. OCT 87 WES/TR/ITL-87-5 F/G 12/5 NL



[illegible]COPY RE[illegible]UTION TEST CHART

57. The final results of Problem 4, paragraph 51a, using the input seepage pressures are shown here, followed by plots of the failure surface and wedges.

```
------------------------------------
  PROGRAM CSLIDE - FINAL RESULTS
------------------------------------

DATE:  86/05/29.                         TIME:  11.58.36.

DAM NO.4

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED FROM INPUT PRESSURES

                    HORIZONTAL LOADS
                    ----------------
                                                VERTICAL
    WEDGE        LEFT  SIDE      RIGHT SIDE       LOAD
    NUMBER        (KIPS)          (KIPS)         (KIPS)
----------------------------------------------------------

      1             .000            .000        128.545
      2           63.281          50.000        498.550
      3             .000            .000         27.349

                 WATER PRESSURES ON WEDGES
                 -------------------------

                      LEFTSIDE WEDGES
                      ---------------

         WEDGE NO.   TOP PRESSURE   BOTTOM PRESSURE
                        (KSF)           (KSF)

            1           2.813           5.492

                      STRUCTURAL WEDGE
                      ----------------

                   X-COORD.    PRESSURE
                    (FT)        (KSF)

                      .00       5.492
                   134.00       3.764
                   275.00       3.319
```

RIGHTSIDE WEDGES

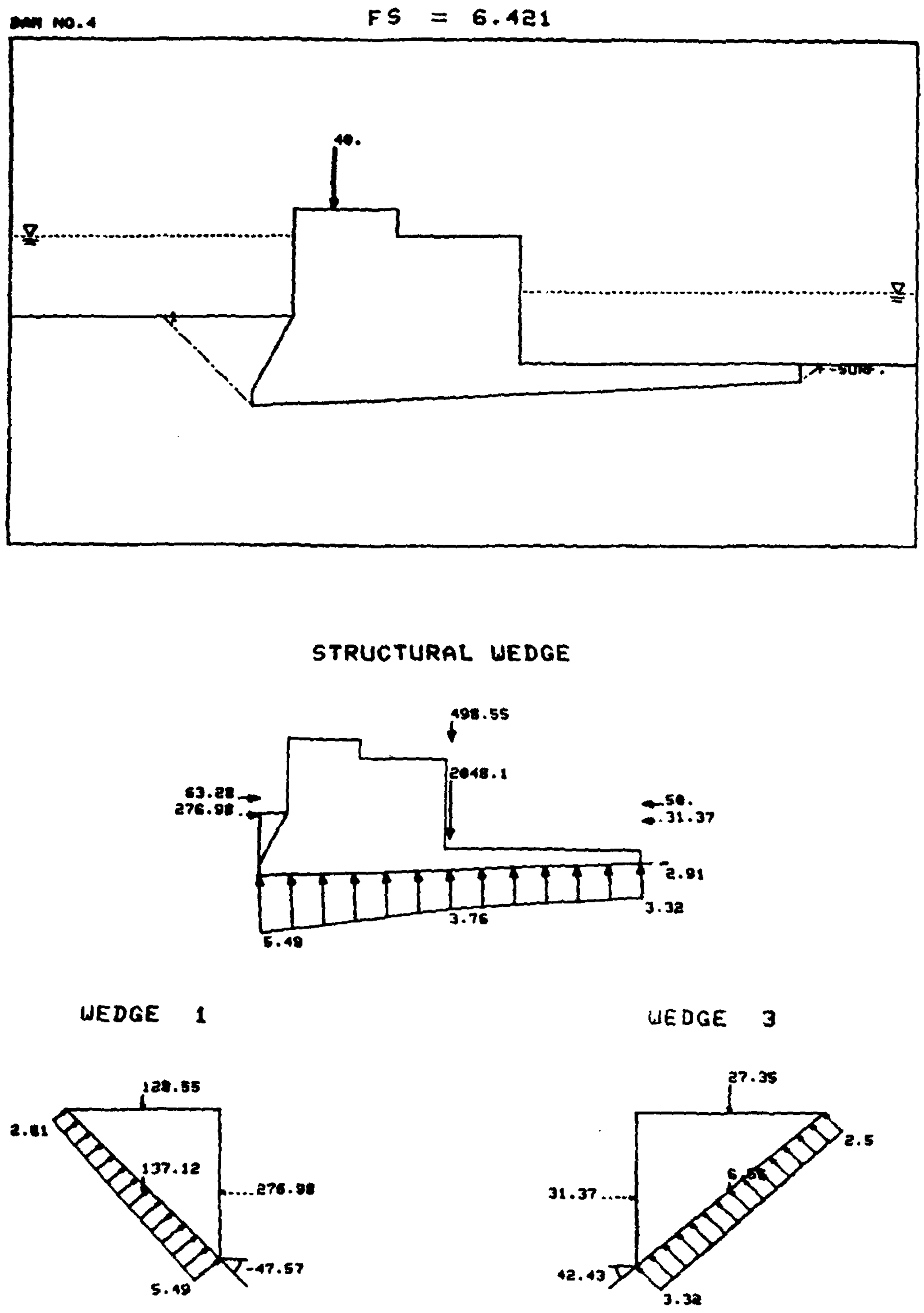
WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	2.500	3.319

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-47.570	67.742	137.115	67.742	281.298
2	2.914	275.356	2048.100	275.356	1120.953
3	42.430	14.822	6.564	14.822	43.123

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-276.981
2	245.607
3	31.375

SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 6.421



Plots of failure surface and wedges, Problem 4
paragraph 51a, input seepage pressures

Edited data entered

```
 DO YOU WISH TO EDIT DATA AND RERUN PROBLEM?
 (ENTER 'Y' OR 'N')
? N

  ***** MODIFIED PROBLEM ENTERED FROM FILE *****

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? N
```

58. The final results of Problem 4, paragraph 51b, using the line-of-creep seepage pressures, are printed here and are followed by plots of the failure surface and wedges.

```
-----------------------------------
   PROGRAM CSLIDE - FINAL RESULTS
-----------------------------------

DATE:  86/05/29.                       TIME:  12.06.16.

DAM NO.4
LINE-OF-CREEP SEEPAGE


SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP


                   HORIZONTAL LOADS
                   ----------------
                                              VERTICAL
    WEDGE        LEFT   SIDE     RIGHT SIDE     LOAD
    NUMBER        (KIPS)          (KIPS)       (KIPS)
-------------------------------------------------


      1             .000            .000      127.769
      2           63.281          50.000      498.550
      3             .000            .000       27.516
```

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	2.813	5.649

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	5.649
275.00	3.183

RIGHTSIDE WEDGES

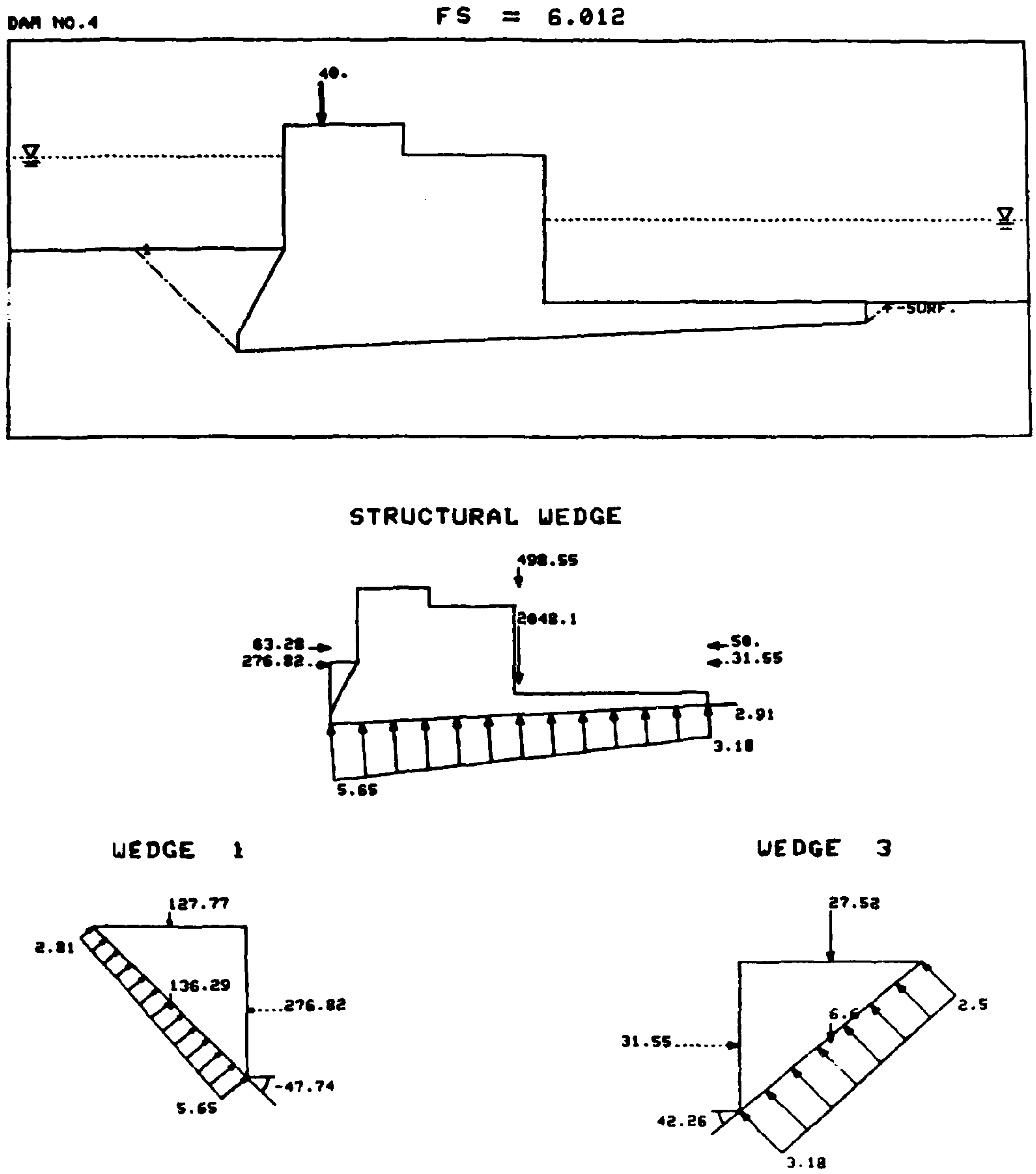
WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	2.500	3.183

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-47.742	67.556	136.287	67.556	285.799
2	2.914	275.356	2048.100	275.356	1215.890
3	42.258	14.871	6.604	14.871	42.253

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-276.822
2	245.276
3	31.547

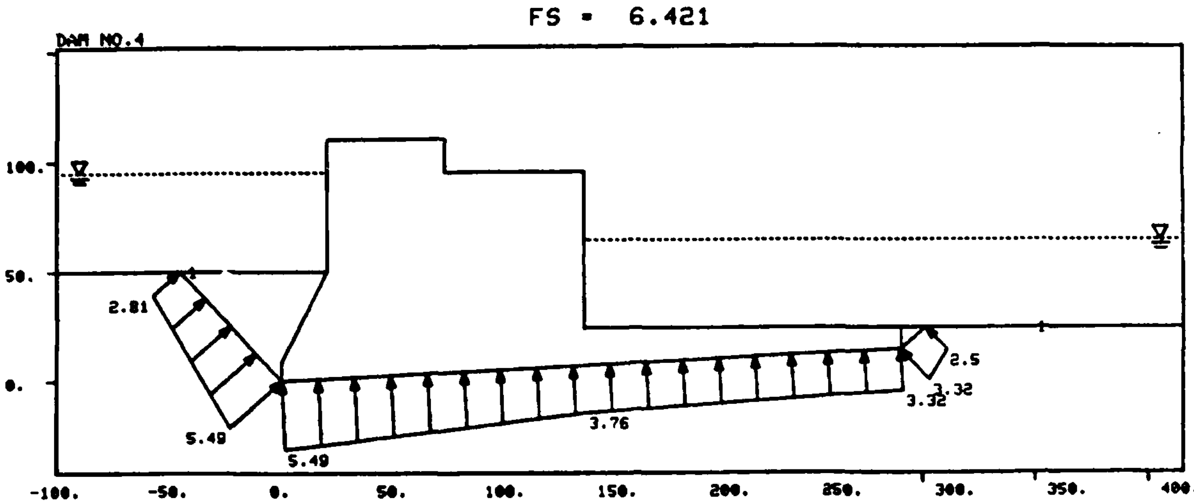
SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 6.012

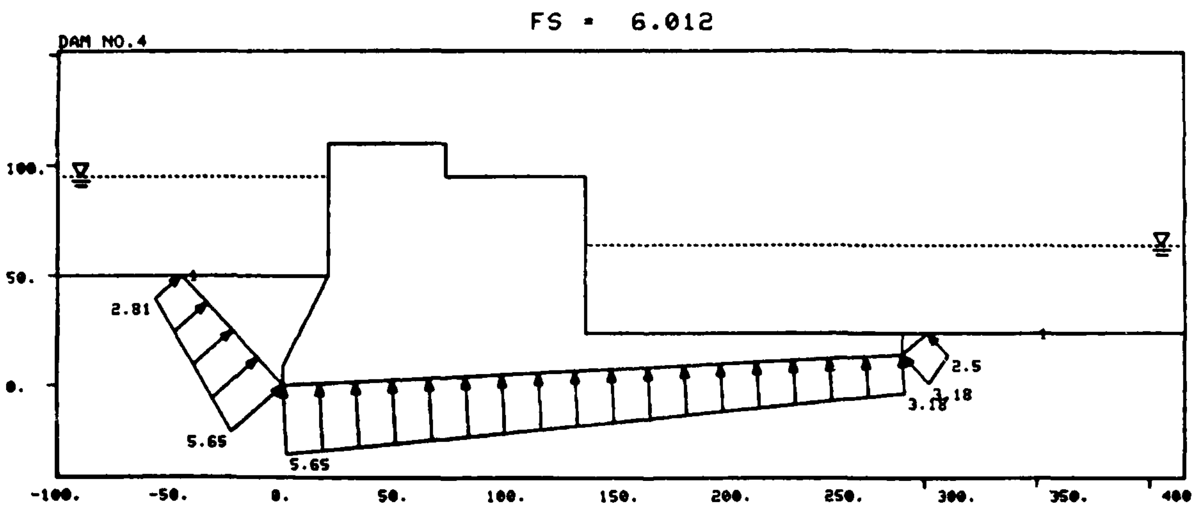


Plot of failure surface and wedges, Problem 4, paragraph 51b, line-of-creep seepage pressures

59. A comparison of water pressures on the failure mechanism, paragraphs 51a and b, are shown in the following drawings.



Input water pressures on the failure mechanism, paragraph 51a



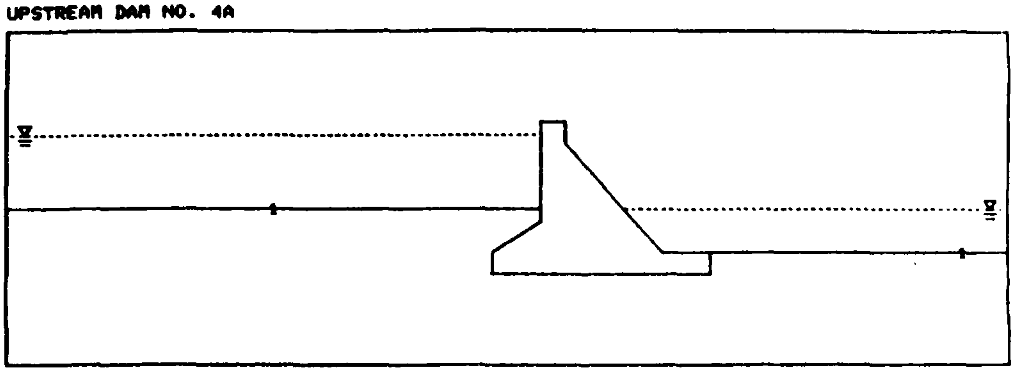
Line-of-creep water pressures on the failure mechanism, paragraph 51b

60. The message shown below indicates CSLIDE has read the data for the new problem, paragraph 51c. A plot of the input data, the final results, and plots of the failure surface and wedges follow.

New data entered

```
 DO YOU WISH TO EDIT DATA AND RERUN PROBLEM?
 (ENTER 'Y' OR 'N')
? N

 ***** NEW PROBLEM ENTERED FROM FILE *****

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? N

 DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
 TERMINAL, FILE, BOTH, OR NEITHER?
 ENTER 'T', 'F', 'B' OR 'N'
? N
```

UPSTREAM DAM NO. 4A



Plot of Input Data, Problem 4, Paragraph 51c

2nd Dam

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/05/29.   TIME: 12.16.40.

UPSTREAM DAM NO. 4A

MULTIPLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	11.537
2	9.031	3.125	26.850
3	.000	.000	4.547

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	1.063	1.755

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.755
45.00	1.019

RIGHTSIDE WEDGES

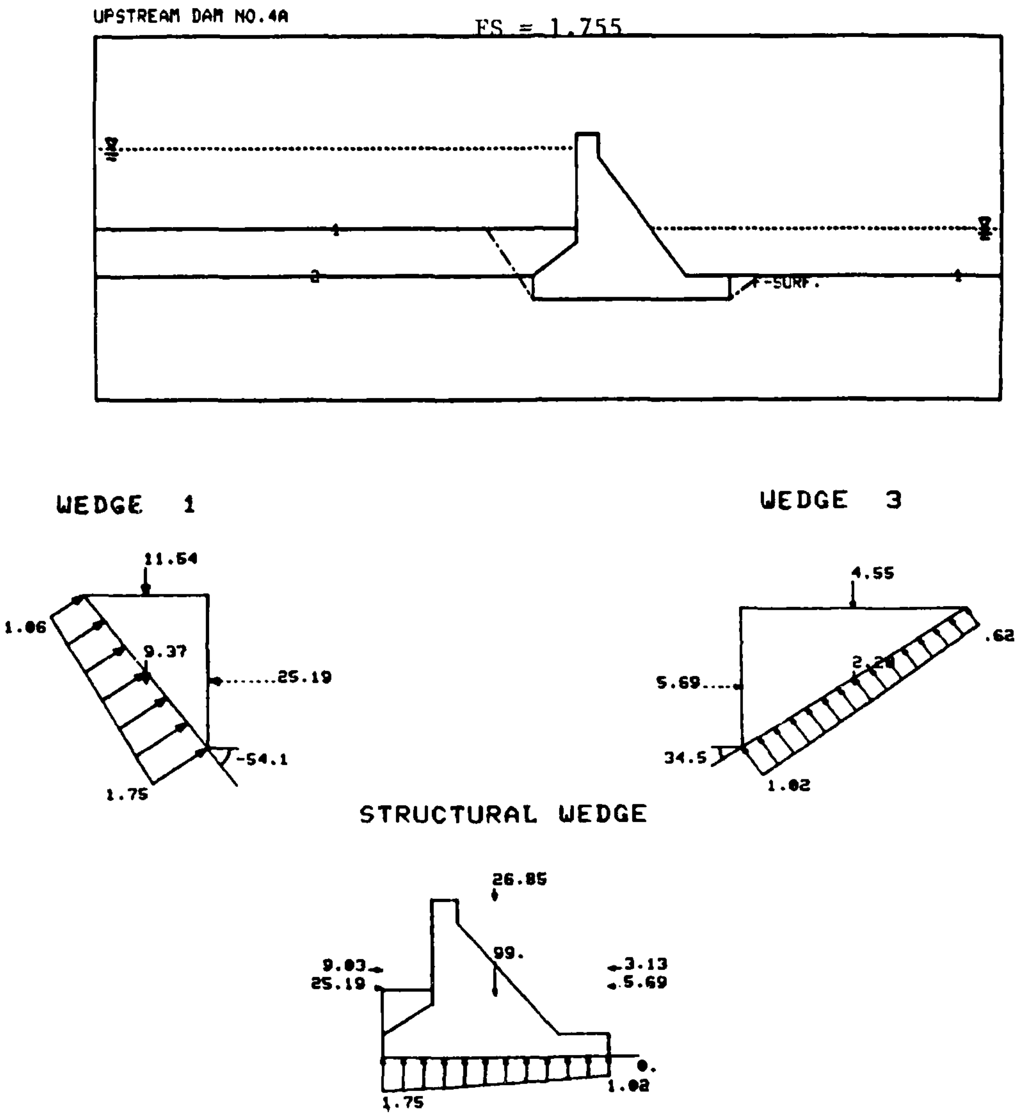
WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.625	1.019

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-54.1	18.518	9.365	18.518	26.085
2	.000	45.000	99.000	45.000	62.416
3	34.5	8.828	2.292	8.828	7.257

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-25.187
2	19.496
3	5.691

SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 1.755



Plot of failure surface and wedges,
Problem 4, paragraph 51c

Problem 5

Summary

61. The purpose of this example is to demonstrate how one may use CSLIDE to determine the net forces corresponding to a specific safety factor. The keyword "FACT" allows the user to enter two values which determine the safety factors used in the first two iterations of the solution process. If the safety factor, for which results are desired, is entered for both of these values, CSLIDE produces results for this desired safety factor only. Unless this safety factor happens to be the actual one which produces equilibrium conditions, the sum of the net forces on the wedges will not be zero. If this sum is a positive number, the actual safety factor is greater than the one entered. If the sum is negative, the actual safety factor is less than the one entered. In this example, a specific safety factor is input and results are obtained. The original default values are used in a second analysis and the solution converges to the actual safety factor at which equilibrium occurs. Plots of the solution convergence can be compared for both of the CSLIDE analyses to show how this option works in the program.

Requirements

62. For this problem, the following are required:

- a. Find the net forces on the system shown in Figure A10 for a sliding safety factor of 1.5.
- b. Find the actual safety factor of this system in equilibrium conditions.

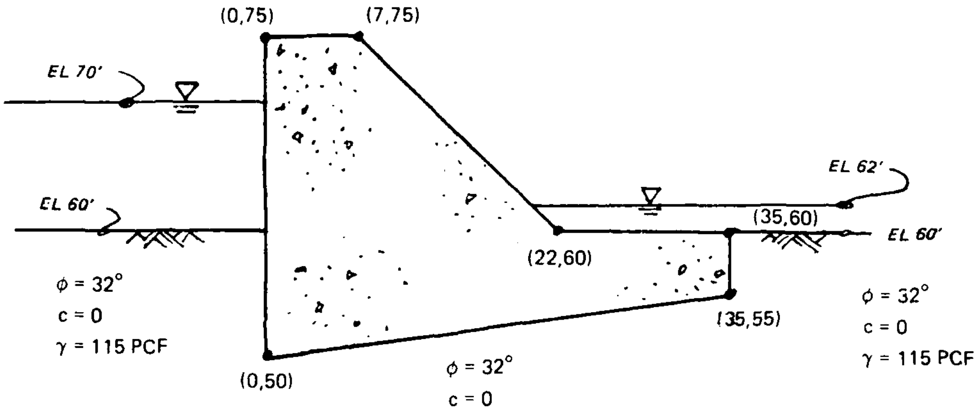


Figure A10. Structure and soil for Problem 5

63. The data file for Problem 5, the echoprint of this input data, and the input plot are shown below.

Data File for Problem 5, Paragraph 60a

```
100 TITL CSLIDE #5
110 STRU 6 .15                        (IPT GAMC)
120      0 50 0 75 7 75
130      22 60 35 60 35 55            Structure Coordinates
140 SOLT 1 1 32 0 .115 60             (NLT LPTS PHIL COL GAML STELL)
150 -100 60                           Soil Layer Coordinate
160 SOST 32 0                         (PHIC CCS)
170 SORT 1 1 32 0 .115 60             (NRT RPTS PHIR COR GAMR STELR)
180 150 60                            Soil Layer Coordinate
190 WATR  70 62 .0625                 (WLL WLR GAMW)
200 METH   1                          (MEAN)
210 FACT 1.5  1.5  1.0                (XLOW UPPER FACTOR)
220 END
```

Echoprint of input data, Problem 5, paragraph 60a

```
------------------------------
  PROGRAM CSLIDE - ECHOPRINT
------------------------------

DATE:  86/06/04.                                    TIME:  08.54.29.

CSLIDE #5

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE BY LINE OF CREEP, GRADIENT
COMPUTED USING SHORTEST SEEPAGE PATH .

NO OF CORNERS IN STRUCTURE ----------         6
DENSITY OF CONCRETE -----------------     .1500(KCF)
DENSITY OF WATER --------------------     .0625(KCF)
WATER LEVEL LEFT SIDE ---------------     70.00(FT)
WATER LEVEL RIGHT SIDE --------------     62.00(FT)
NO. OF SOIL LAYERS LEFT SIDE --------         1
NO. OF SOIL LAYERS RIGHT SIDE -------         1


STRUCTURE INFORMATION
---------------------

POINT          X-COORD        Y-COORD
-----          -------        -------


   1               .00          50.00
   2               .00          75.00
   3              7.00          75.00
   4             22.00          60.00
   5             35.00          60.00
   6             35.00          55.00
```

LEFTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	32.00	.0000	.115	60.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	-100.00	60.00

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 32.00
COHESION --------------- .0000

RIGHTSIDE SOIL DATA

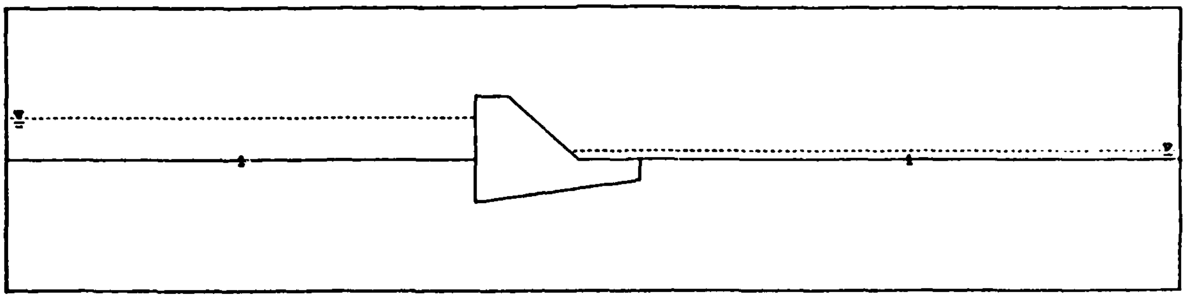
LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	32.00	.0000	.115	60.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	150.00	60.00

SAFETY FACTOR DESCRIPTION

LOWER LIMIT OF F.S. ----- 1.50
UPPER LIMIT OF F.S. ----- 1.50

CSLIDE #5



Plot of input data

64. In this first analysis, equilibrium was not achieved due to the unbalanced net force on the system. Therefore, the label "Stationary Solution" appears to indicate this condition. Results of the stationary solution for Problem 5, paragraph 60a, are shown below, followed by the failure surface and convergence plots.

```
-----------------------
  STATIONARY SOLUTION
-----------------------



DATE:  86/06/04.                          TIME:  08.55.21.

CSLIDE #5


SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP


                     HORIZONTAL LOADS
                     ----------------         VERTICAL
   WEDGE         LEFT  SIDE      RIGHT SIDE      LOAD
   NUMBER         (KIPS)          (KIPS)        (KIPS)
-------------------------------------------------------


     1            .000            .000          4.167
     2           3.125            .125          1.750
     3            .000            .000           .937


        WATER PRESSURES ON WEDGES
        -------------------------
              LEFTSIDE WEDGES
              ---------------

WEDGE NO.   TOP PRESSURE   BOTTOM PRESSURE
               (KSF)            (KSF)


    1           .625           1.151

              STRUCTURAL WEDGE
              ----------------

          X-COORD.    PRESSURE
           (FT)         (KSF)


            .00        1.151
          35.00         .487
```

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.125	.487

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-56.307	12.019	3.834	12.019	10.671
2	8.130	35.355	72.000	35.355	28.953
3	33.693	9.013	2.156	9.013	2.759

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-10.266
2	27.914
3	2.727

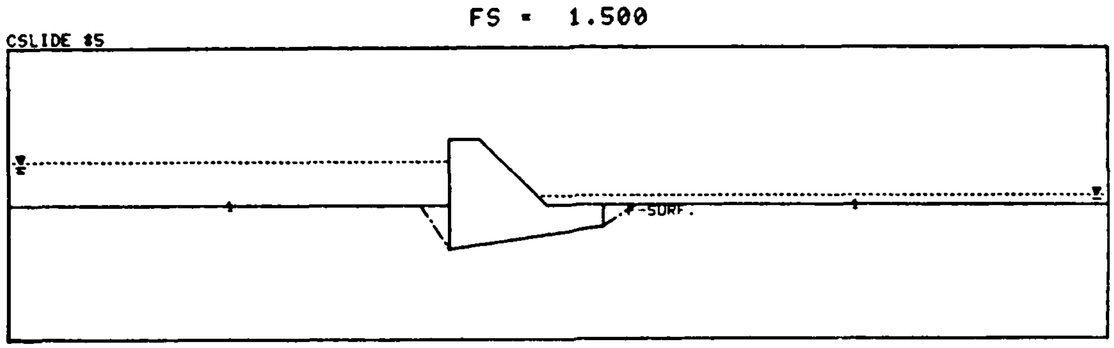
SUM OF FORCES ON SYSTEM ---- 20.376

FACTOR OF SAFETY ----------- 1.500

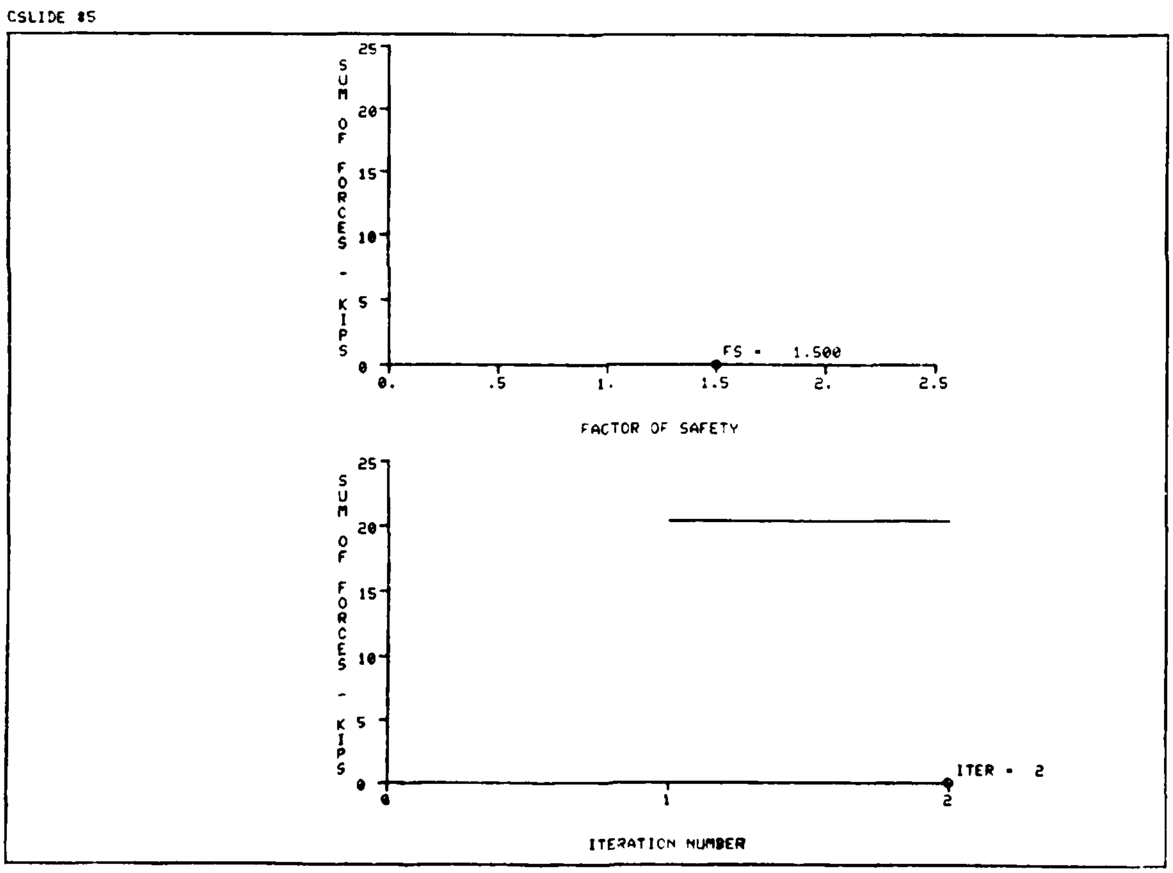
* NOTE * THE SOLUTION HAS NOT CONVERGED.

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.
?

The positive sum of forces indicates the actual safety factor to be greater than 1.5.



Failure surface, Problem 5, paragraph 60a



Convergence plots, Problem 5, paragraph 60a

65. Data are edited with keywords to change the safety factor iteration limits to the original (default) values of 0.5 and 1.5. Following this, the final results are shown.

```
 DO YOU WANT TO EDIT YOUR DATA?
? Y

 DO YOU WANT TO EDIT USING KEYWORDS
 OR SECTIONS ? (ENTER 'K' OR 'S')
? K
 ENTER KEYWORD. TYPE 'END' TO EXIT, 'LIST

 TO LIST KEYWORDS
? FACT .5 1.5 1.0

 NEXT?
? END
```

Replace the input safety factor with the original (default) values.

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/05/30. TIME: 15.20.47.

CSLIDE #5

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	5.975
2	3.125	.125	1.750
3	.000	.000	.654

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.625	1.151

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	1.151
35.00	.487

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.125	.487

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-46.288	13.835	5.497	13.835	12.283
2	8.130	35.355	72.000	35.355	28.953
3	43.712	7.236	1.504	7.236	2.215

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-11.731
2	9.619
3	2.113

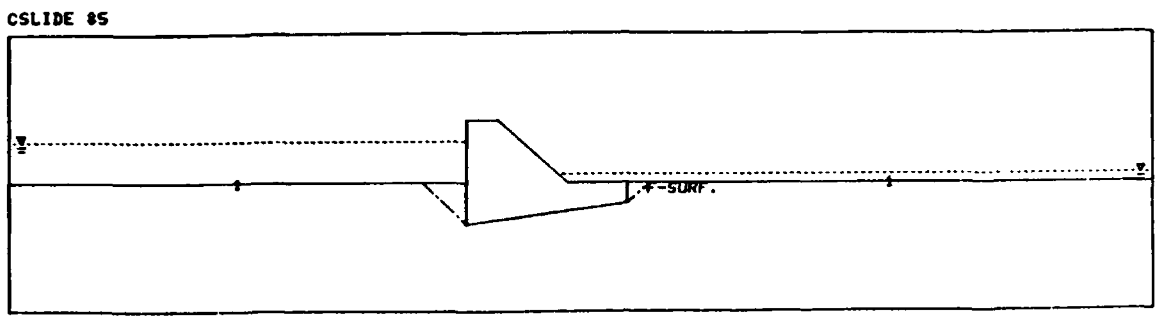
SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 13.887

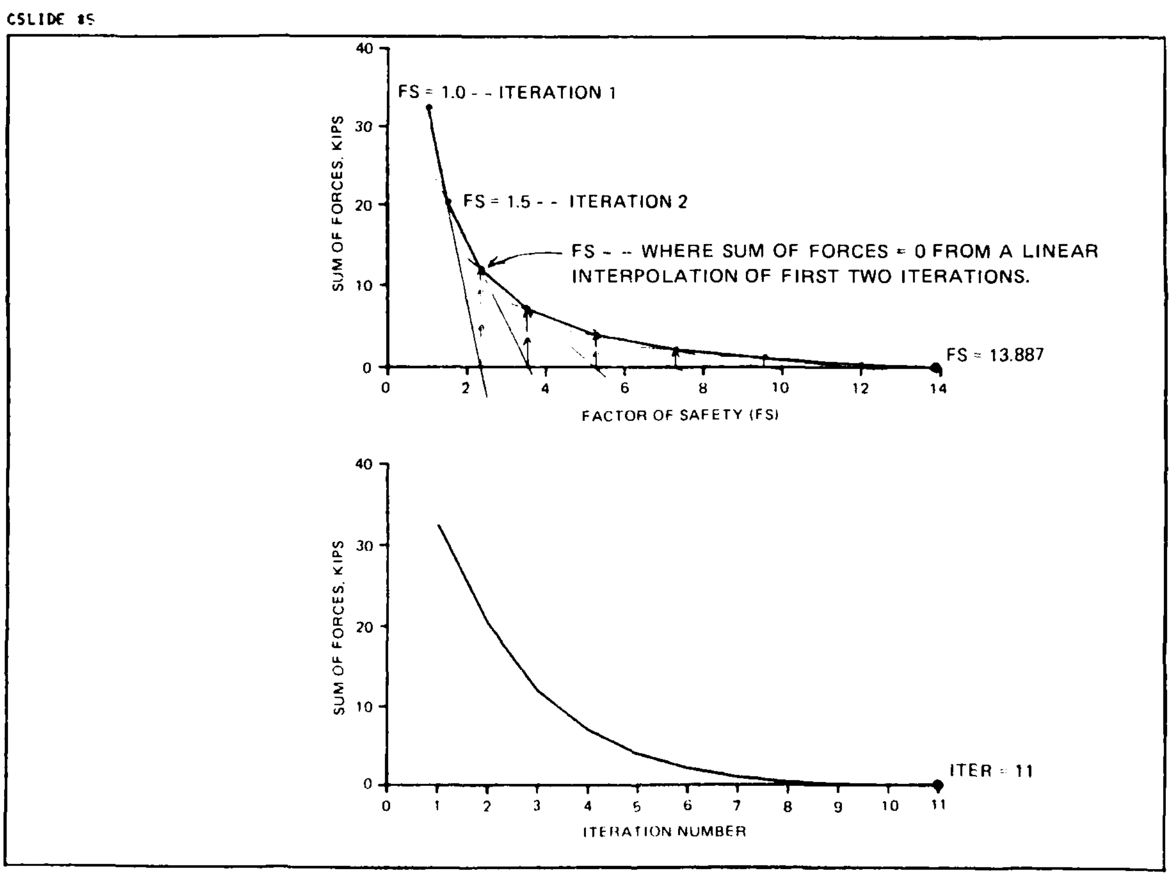
Actual safety factor for equilibrium conditions. The solution has converged.

DO YOU WANT TO PLOT RESULTS? ENTER 'Y' OR 'N'.

66. The concluding material for Problem 5 includes plots of the failure surface and the solution convergence for paragraph 60b.



Failure surface, Problem 5, paragraph 60b



Convergence plots, Problem 5, paragraph 60b

Problem 6

Summary

67. This example problem demonstrates how one may reduce the passive forces in a CSLIDE analysis. In cases where full passive resistance does not develop, one would reduce or exclude the passive force in the sliding analysis. The retaining wall system in this example is such a case. An option in CSLIDE called the passive-to-active safety-factor ratio is used to increase the passive safety factor, with respect to the active safety factor, thereby reducing passive soil resistance.

68. An equilibrium analysis is performed to determine the equilibrium safety factor. The full passive resistance for this system can be obtained from the results of the first iteration, in which the safety factor is one. The value of this fully developed passive force is required in order to determine how much it is actually reduced in subsequent analyses. A second analysis is run using a passive-to-active ratio (under keyword "FACT") of 4.0 to reduce passive resistance. Results are discussed following the CSLIDE solution.

Requirements

69. For this problem, the following are required:

- a. To find the equilibrium safety factor of the wall shown in Figure A11, and to find the full passive force value from the first iteration of the solution.
- b. To run a second analysis using a safety factor ratio of 4.0 ($FS_{passive} = 4$, $FS_{active} = 1$), and compare the net forces from both analyses.

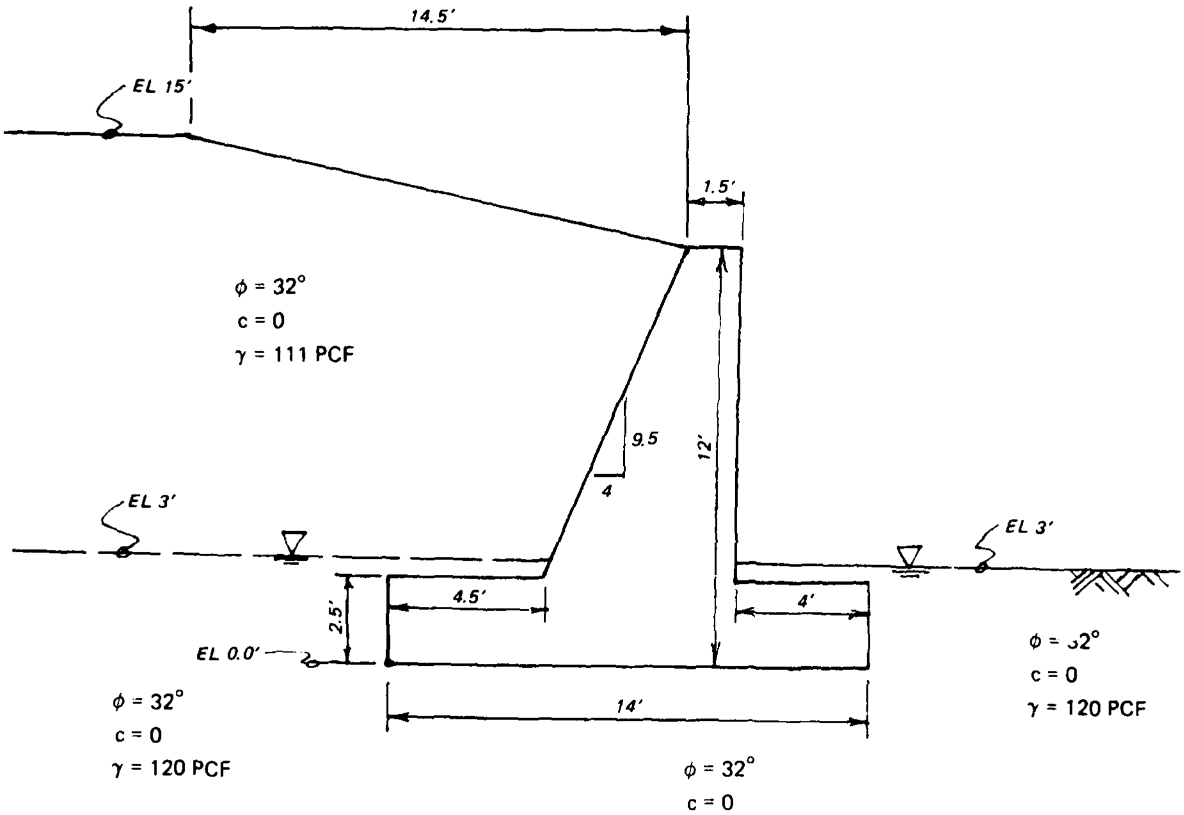
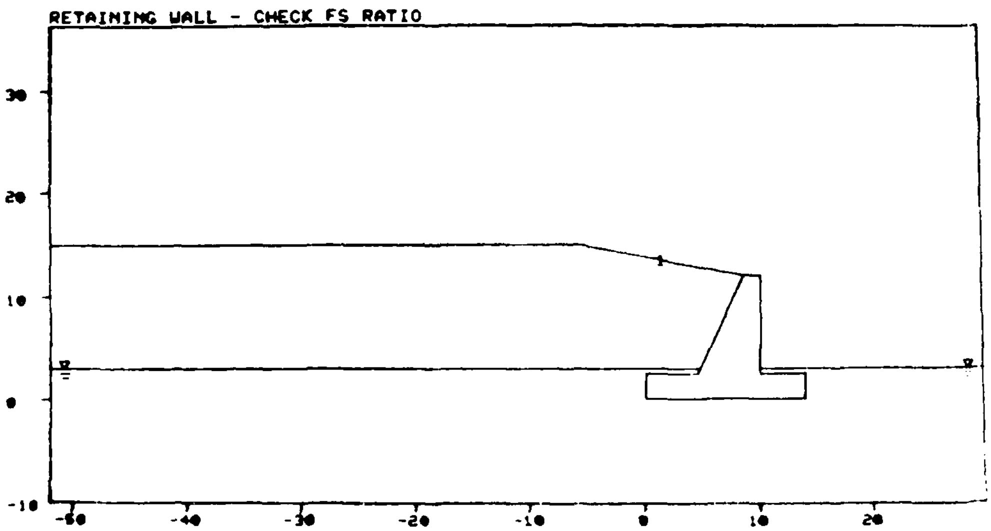


Figure A11. Structure and soil for Problem 6

70. The data file for Problem 6 and a plot of the input data are shown below. These are followed by the results of the first iterations, the final results, and plots of the failure surface and wedges.

Data File for Problem 6, Paragraph 67a.

```
100 TITL RETAINING WALL - CHECK FS RATIO
110 TITL FSP/FSA= 1.0
120 STRU 8 .15                       (IPT GAMC)
130 0 0  0 2.5  4.5 2.5  8.5 12
140 10 12  10 2.5  14 2.5  14 0      Structure Coordinates
150 SOLT 1 2 32 0 .111 12            (NLT LPTS PHIL COL GAML STELL)
160 -500 15 -6 15                    Soil Layer Coordinates
170 SOLT 2 1 32 0 .120 3             (NLT LPTS PHIL COL GAML STELL)
180 -500 3                           Soil Layer Coordinate
190 SOST 32  0                       (PHIC CCS)
200 SORT 1 1 32 0 .120  3            (NRT RPTS PHIR COR GAMR STELR)
210 500 3                            Soil Layer Coordinate
220 WATR 3 3 .0625                   (WLL WLR GAMW)
230 METH  1                          (MEAN)
240 END
```



Plot of input data

TEMPORARY RESULTS AFTER ITERATION 1

DATE: 87/06/10. TIME: 08.44.33.

RETAINING WALL - CHECK FS RATIO
FSP/FSA = 1.0

SINGLE FAILURE PLANE ANALYSIS

HYDROSTATIC WATER FORCE COMPUTED FOR WEDGES

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	7.945
4	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.000
2	.000	.188

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	.188
14.00	.188

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
4	.000	.188

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-59.642	13.907	4.474	.000	.000
2	-59.642	3.477	2.450	3.477	.326
3	.000	14.000	10.238	14.000	2.625
4	29.000	6.188	.974	6.188	.580

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-2.343
2	-1.478
3	9.721
4	1.123

SUM OF FORCES ON SYSTEM ---- 7.023

FACTOR OF SAFETY ----------- 1.000

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/06/04. TIME: 11.59.36.

RETAINING WALL - CHECK FS RATIO
FSP/FSA = 1.0

SINGLE FAILURE PLANE ANALYSIS

HYDROSTATIC WATER FORCE COMPUTED FOR WEDGES

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	7.945
4	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.000
2	.000	.188

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE ERR.. (KSF)
.00	.188
14.00	.188

RIGHTSIDE WEDGES

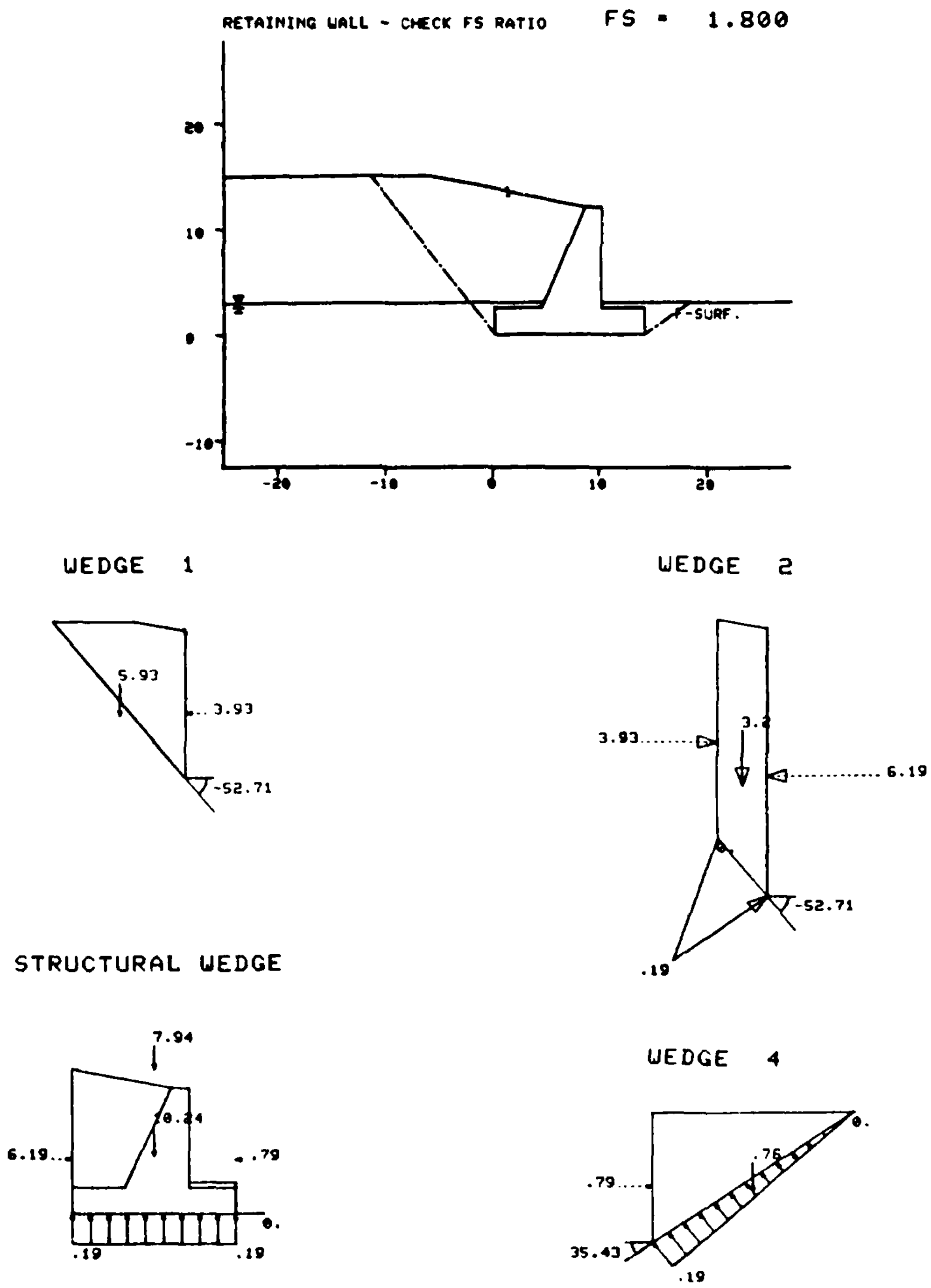
WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
4	.000	.188

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-52.707	15.084	5.928	.000	.000
2	-52.707	3.771	3.200	3.771	.354
3	.000	14.000	10.238	14.000	2.625
4	35.426	5.176	.759	5.176	.485

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-3.933
2	-2.262
3	5.402
4	.793

SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 1.800



Failure surface and wedges for Problem 6, paragraph 67a

71. Data is edited with keywords to change the FS ratio to 4.0 for the second analysis. Final results are shown below.

Input an FS Ratio of 4.0

```
 DO YOU WANT TO EDIT YOUR DATA?
? Y

 DO YOU WANT TO EDIT USING KEYWORDS
 OR SECTIONS ? (ENTER 'K' OR 'S')
? K

 ENTER KEYWORD. TYPE 'END' TO EXIT, 'LIST'
 TO LIST KEYWORDS
? FACT .5 1.5 4.0

 NEXT?
? END
```

```
 -------------------------------------
   PROGRAM CSLIDE - FINAL RESULTS
 -------------------------------------

 DATE:  86/06/04.                    TIME:  12.12.55.

 RETAINING WALL - CHECK FS RATIO
 FSP/FSA = 1.0

 SINGLE FAILURE PLANE ANALYSIS

 HYDROSTATIC WATER FORCE COMPUTED FOR WEDGES
```

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	7.945
4	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.000
2	.000	.188

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
.00	.188
14.00	.188

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
4	.000	.188

WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-52.923	15.041	5.879	.000	.000
2	-52.923	3.760	3.174	3.760	.353
3	.000	14.000	10.238	14.000	2.625
4	42.466	4.443	.590	4.443	.417

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-3.875
2	-2.234
3	5.519
4	.590

The safety factor shown is for the active side and structural wedge only. Therefore the passive side has a safety factor of

1.761 X 4 = 7.044

SUM OF FORCES ON SYSTEM ---- .000

FACTOR OF SAFETY ----------- 1.761

72. By increasing the safety factor of the passive side, the strength parameters ϕ and c are not developed as much as they are on the active side.

$$\phi_d = \tan^{-1}\left(\frac{\tan\phi}{FS}\right) \qquad c_d = \frac{c_i}{FS}$$

While this reduces the strength of the passive soil, the ratio of 4:1 is <u>not</u> a direct measure of this strength reduction.

73. To assess the reduction in strength on the passive side due to the passive FS increase, the net forces of wedge 4 are compared:

FS_{active}	$FS_{passive}$	Ratio of $FS_{passive}$ to FS_{active}	Net Force of Wedge 4 (kips)	Percent Reduction
1.000	1.000	1.0	1.123 (fully developed)	0.0
1.800	1.800	1.0	0.793 (balance point, par. 67)	29.4
1.761	7.044	4.0	0.590	47.5

If the net force from the passive wedge should be less than 0.590 kips, the problem should be reanalyzed using a larger FS ratio. If the passive net force should be greater than 0.590 kips, decrease the FS ratio.

Problem 7

Summary

74. This example is a CSLIDE analysis of a U-wall. Earthquake conditions are applied to the system and resulting forces are determined for a specific safety factor.

75. If a channel-type structure, as shown in Figure A12, has soil or water elevations above either one or both sides of the channel, CSLIDE computes the horizontal and vertical loads of that part of the material which lies within the channel. Otherwise, if soil or water elevations are at or below both sides of the channel, any loads within the channel must be modeled by the user as external horizontal and vertical loads on the structural wedge.

Requirements

76. The requirement of this problem is to determine the resulting forces on the system, shown in Figure A12, for a safety factor of 1.10 and a horizontal earthquake acceleration coefficient of 0.20.

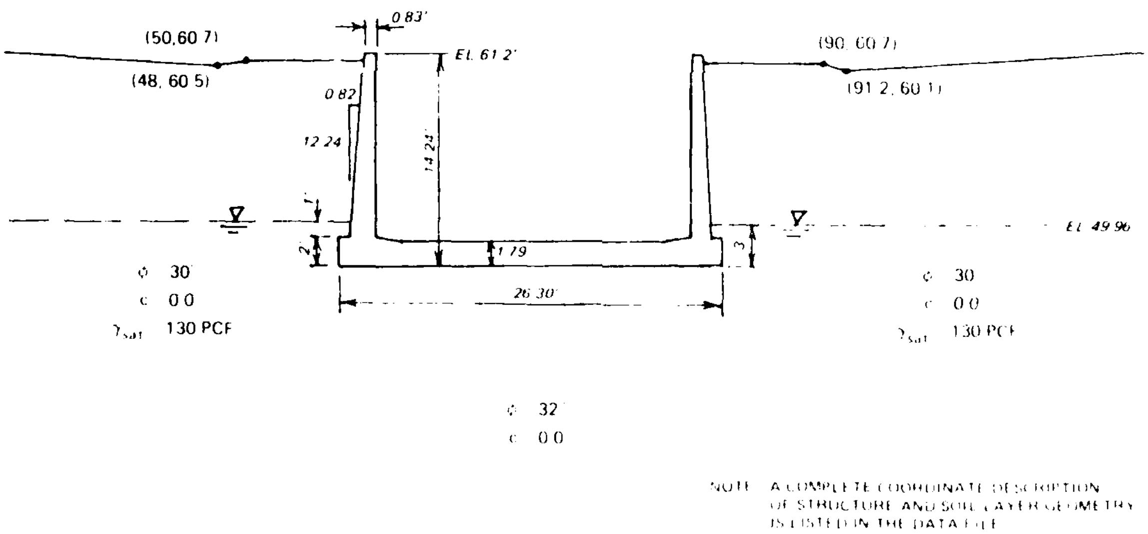


Figure A12. U-wall, Problem 7, soil-structure system

77. The data file for Problem 7, the echoprint, and a plot of the input data are shown on the following pages.

Data file for Problem 7, U-wall

```
150 TITL U-WALL CHANNEL
160 STRU 14 .150 46.96 .50     (IPT GAMC ANEL FL)
170      56.85 46.96
180      56.85 48.96
190      57.35 48.96
200      58.17 61.20
210      59.00 61.20
220      59.00 48.96
230      60.88 48.75
240      79.12 48.75          Structure Coordinate Points
250      81.00 48.96
260      81.00 61.20
270      81.83 61.20
280      82.65 48.96
290      83.15 48.96
300      83.15 46.96
310 SOLT 1 5 30 0 .130 60.70   (NLT LPTS PHIL COL GAML STELL)
320       3.50 64.00
330      16.50 64.00
340      24.50 62.00          Soil Layer Coordinate  Points
350      48.00 60.50
360      50.00 60.70
370 SORT 1 3 30 0 .130 60.7    (NRT RPTS PHIR COR GAMR STELR)
380      90.00 60.70
390      91.20 60.10          Soil Layer Coordinate Points
400     134.50 61.50
410 SOST 32 0                  (PHIC CCS)
420 METH  2                    (MEAN)
430 WATR 49.96  49.96 .0625 -1 (WLL WLR GAMW S)
440 EQAC  .00  .20             (EQVT EQHO)
450 FACT  1.10  1.10  1        (XLOW UPPER FACTOR)
460 END
```

Echoprint of Input Data - Problem 7

PROGRAM CSLIDE - ECHOPRINT

DATE: 86/07/01. TIME: 14.09.05.

U-WALL CHANNEL

MULTI FAILURE PLANE ANALYSIS

HYDROSTATIC WATER FORCE COMPUTED FOR WEDGES

NO OF CORNERS IN STRUCTURE ---------- 14
DENSITY OF CONCRETE ----------------- .1500(KCF)
DENSITY OF WATER -------------------- .0625(KCF)
WATER LEVEL LEFT SIDE --------------- 49.96(FT)
WATER LEVEL RIGHT SIDE -------------- 49.96(FT)
NO. OF SOIL LAYERS LEFT SIDE -------- 1
NO. OF SOIL LAYERS RIGHT SIDE ------- 1

ELEV. OF WEDGE-STRUCTURE INTERSECTION
ON ACTIVE SIDE OF STRUCTURE --------- 46.960(FT)

STRUCTURE INFORMATION

POINT	X-COORD	Y-COORD
1	56.85	46.96
2	56.85	48.96
3	57.35	48.96
4	58.17	61.20
5	59.00	61.20
6	59.00	48.96
7	60.88	48.75
8	79.12	48.75
9	81.00	48.96
10	81.00	61.20
11	81.83	61.20
12	82.65	48.96
13	83.15	48.96
14	83.15	46.96

50.00 % OF THE STRUCTURAL BASE IS IN COMPRESSION

LEFTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.130	60.70

LAYER	POINT NO. 1		POINT NO. 2		POINT NO. 3	
NO	X-COORD	Y-COORD	X-COORD	Y-COORD	X-COORD	Y-COORD
1	3.50	64.00	16.50	64.00	24.50	62.00

LAYER	POINT NO. 4		POINT NO. 5	
NO	X-COORD	Y-COORD	X-COORD	Y-COORD
1	48.00	60.50	50.00	60.70

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 32.00
COHESION --------------- .0000

RIGHTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.130	60.70

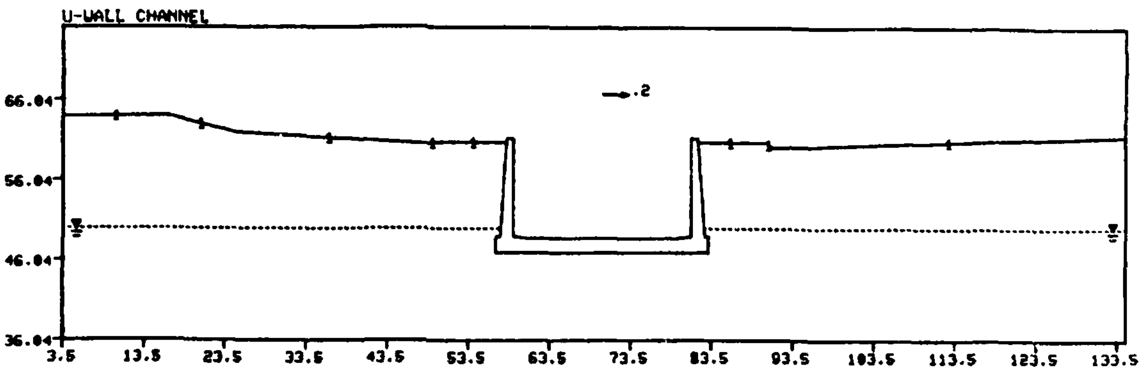
LAYER NO	POINT NO. 1 X-COORD	POINT NO. 1 Y-COORD	POINT NO. 2 X-COORD	POINT NO. 2 Y-COORD	POINT NO. 3 X-COORD	POINT NO. 3 Y-COORD
1	90.00	60.70	91.20	60.10	134.50	61.50

SEISMIC ACCELERATIONS

VERTICAL --------- .000
HORIZONTAL ------- .200

SAFETY FACTOR DESCRIPTION

LOWER LIMIT OF F.S. ----- 1.10
UPPER LIMIT OF F.S. ----- 1.10



Plot of input data

78. Results of the U-wall analysis and plots of the failure surface and wedges are shown on the following pages. The heading, "Stationary Solution" indicates the solution did not converge because the safety factor was fixed in the input using the "FACT" command.

STATIONARY SOLUTION

DATE: 86/06/30. TIME: 16.44.37.

U-WALL CHANNEL

MULTIPLE FAILURE PLANE ANALYSIS

HYDROSTATIC WATER FORCE COMPUTED FOR WEDGES

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	2.296	.000	.000
2	2.907	.000	2.727
3	4.490	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	.000	.188

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
56.85	.188
83.15	.188

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.000	.188

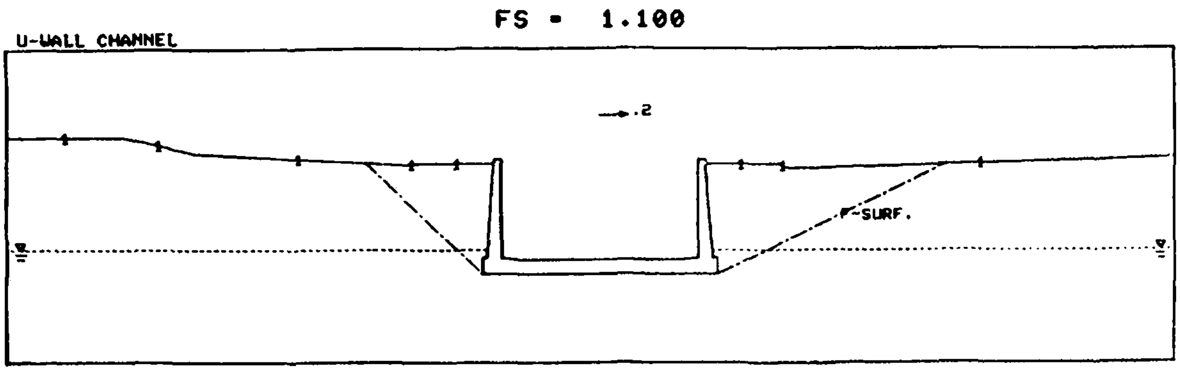
WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-46.7	18.953	11.482	4.119	.386
2	.000	26.300	11.810	26.300	4.931
3	27.9	29.364	22.452	6.421	.602

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-6.452
2	2.549
3	27.740

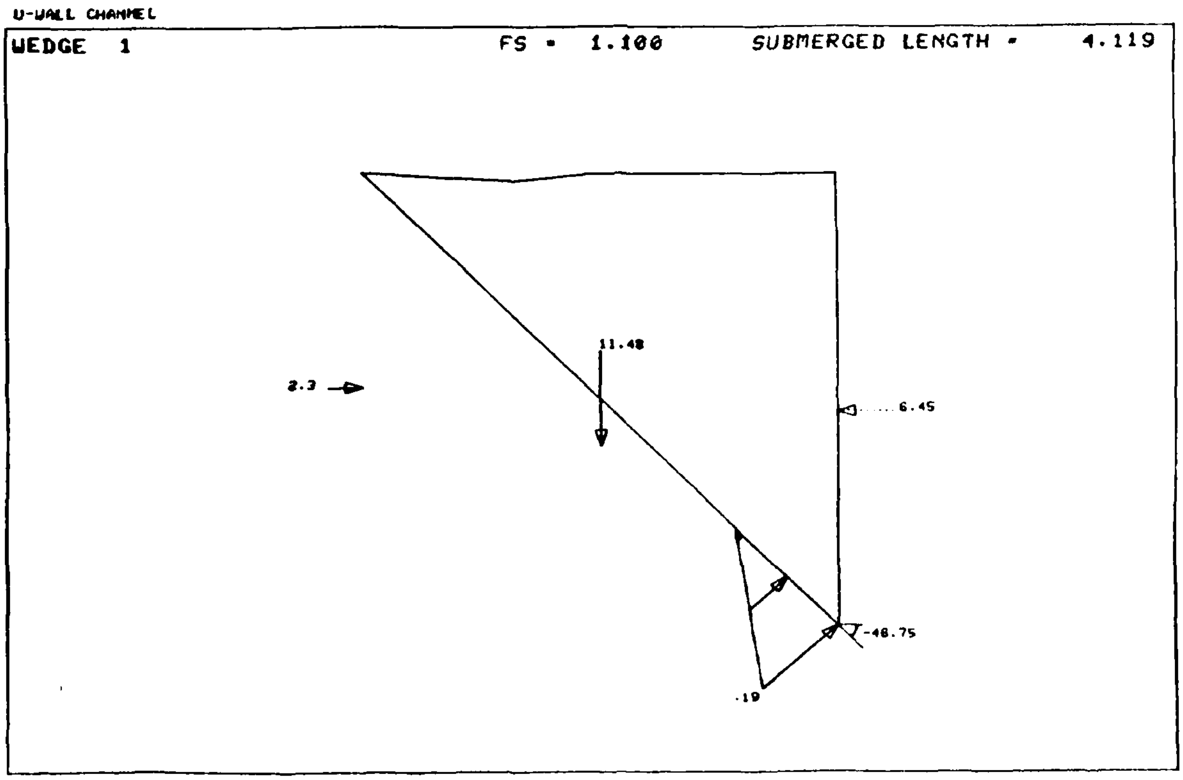
SUM OF FORCES ON SYSTEM ---- 23.837

FACTOR OF SAFETY ----------- 1.100

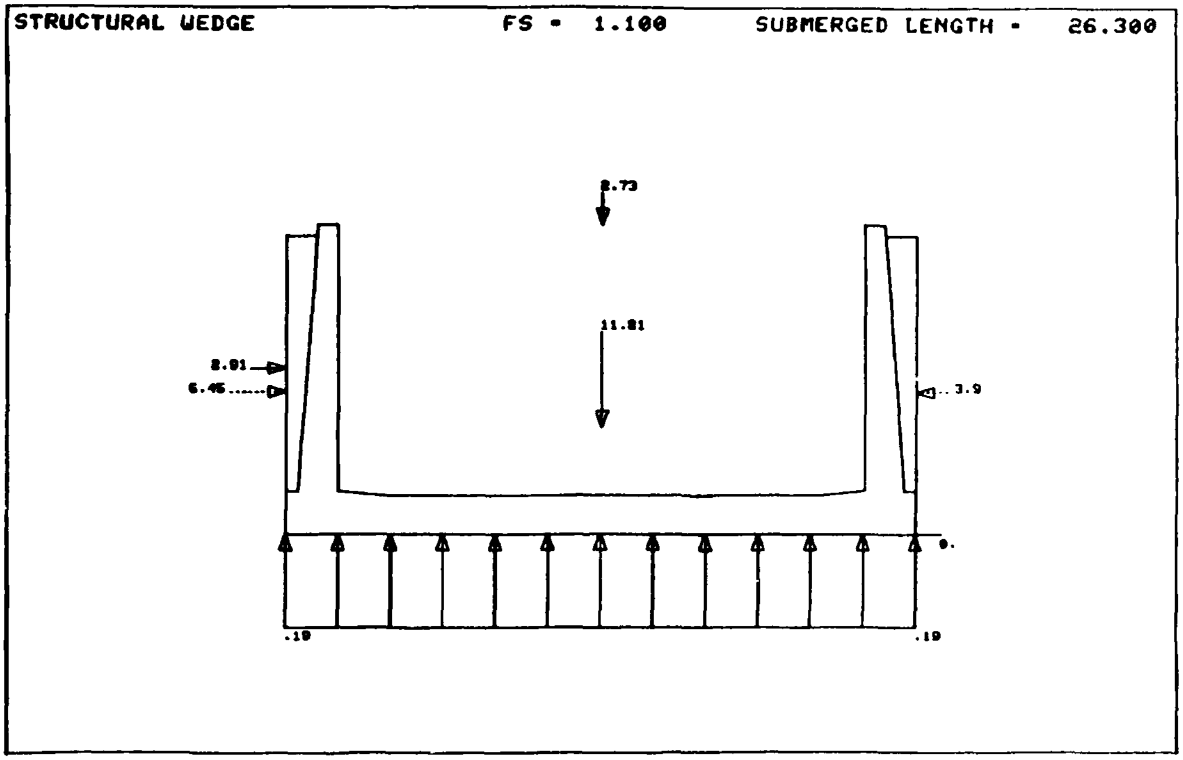
* NOTE * THE SOLUTION HAS NOT CONVERGED.



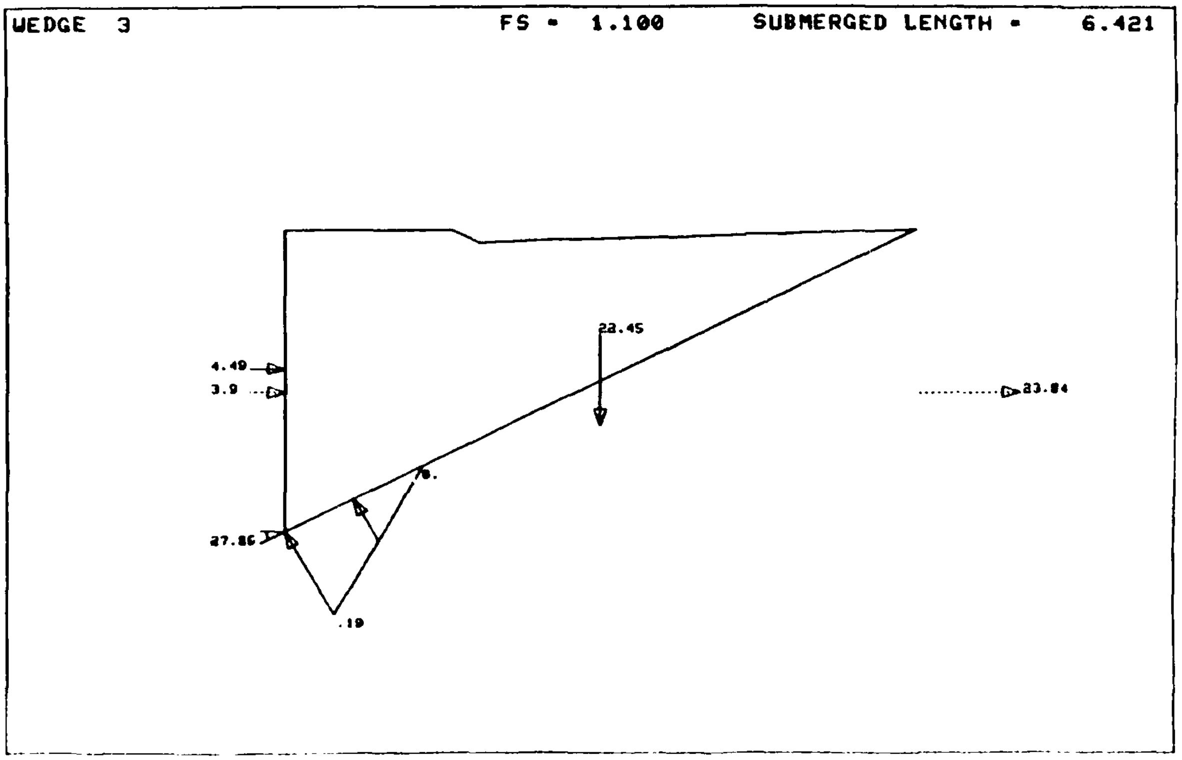
Plot of failure surface



U-WALL CHANNEL



U-WALL CHANNEL



APPENDIX B: COMPLETE HAND SOLUTIONS FOR PROGRAM VERIFICATION

Problem	Description	Page
1	Hand-calculated iterations using trial safety factors to determine the failure mechanism and safety factor of a retaining wall supporting a sloped backfill. Comments on failure angle hand calculations for wedges that do not meet the Coulomb wedge criteria. CSLIDE analysis and comparison of hand and CSLIDE results.	B6
2	Hand-calculated iterations for the safety factor and failure mechanism of a gravity dam. CSLIDE analysis and a hand check of the CSLIDE safety factor.	B41

Summary

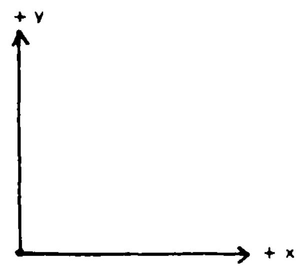
1. The two examples contained in this appendix are long-hand solutions which calculate the factor of safety and failure mechanism of the retaining wall shown in Figure B1 and the dam shown in Figure B2. Following each hand solution is a CSLIDE analysis of the same problem and a chart comparing results between hand and CSLIDE calculations.

2. The solution procedure used follows the method outlined in ETL 1110-2-256.

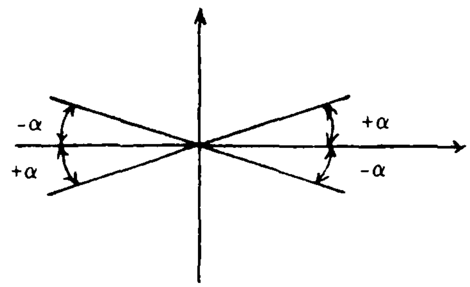
3. The sign convention is explained in the drawing which follows.

Appendix B

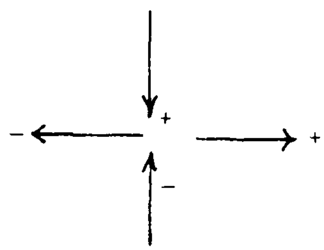
Sign Convention



COORDINATE SYSTEM FOR GEOMETRY OF THE SOIL AND STRUCTURE.



ANGLES



FORCES

The general wedge equation for wedge, i :

$$P_{i-1} - P_i = \frac{\left[(W_i + V_i)\cos\alpha_i - U_i + (H_{L_i} - H_{R_i})\sin\alpha_i\right]\dfrac{\tan\phi_i}{FS_i}}{\cos\alpha_i - \sin\alpha_i\left(\dfrac{\tan\phi_i}{FS_i}\right)}$$

$$+ \frac{-(H_{L_i} - H_{R_i})\cos\alpha_i + (W_i + V_i)\sin\alpha_i + \dfrac{c_i}{FS_i} L_i}{\cos\alpha_i - \sin\alpha_i\left(\dfrac{\tan\phi_i}{FS_i}\right)}$$

The terms of the equation are described in Appendix D, Notation.

Problem 1

4. The following is a discussion of certain parts of the procedure used in the hand solution of Problem 1.

5. Use of the Coulomb method for computing a failure plane angle of $\alpha = (45 \pm \phi_d/2)$ through a soil layer requires that the following conditions be met:

   a. The soil layer in which a wedge is formed must be a horizontal uniform layer.

   b. The soil layer must be completely saturated or completely unsaturated.

   c. If external loads or other soil layers are present, they must be uniform over the entire surface of the soil layer.

6. In this problem, the top soil layer on the active side (left) is sloped (see Figure B1). To calculate a trial failure angle for wedge 1, the following hand solution uses an equation presented in the draft Engineer Manual, "T-Wall Manual, Retaining and Flood Walls."* This appears in Problem 1, paragraph 9b.

7. Wedge 2 forms in soil layer 2, which has a horizontal surface. However, the soil of layer 1, which acts as a surcharge on layer 2, is sloped, making it a nonuniform surcharge. The hand solution uses $(45 \pm \phi_d/2)$ to calculate trial failure angles for this wedge, because no technique which accounts for these conditions had been found at the time this hand solution was performed.

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* Headquarters, Department of the Army. In preparation. "Retaining and Flood Walls."

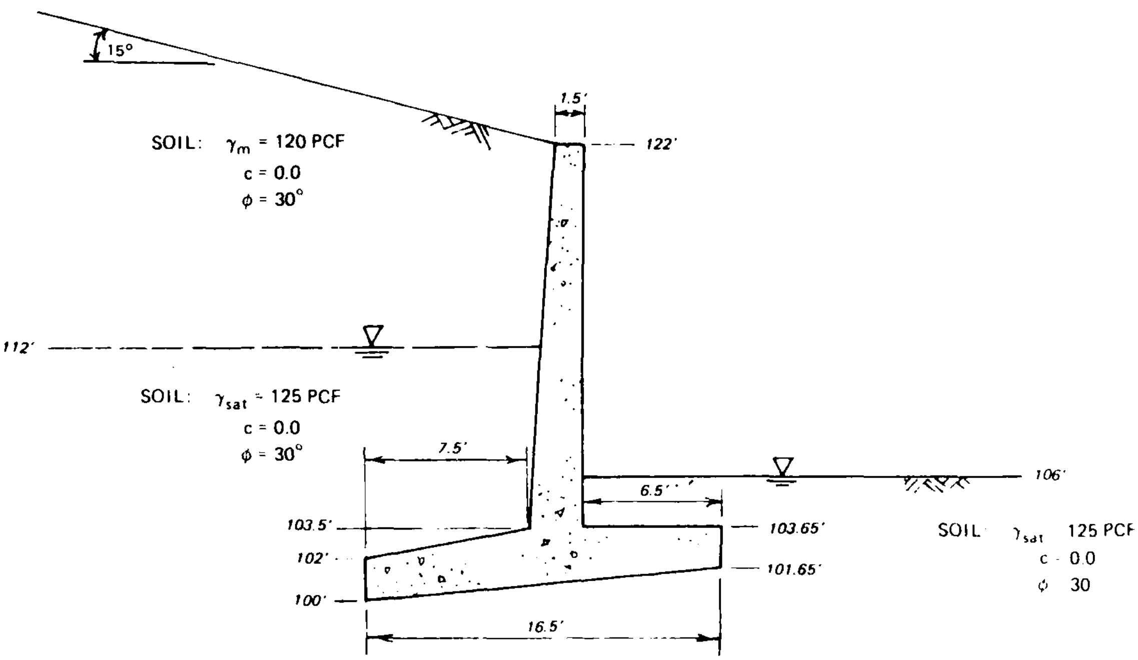
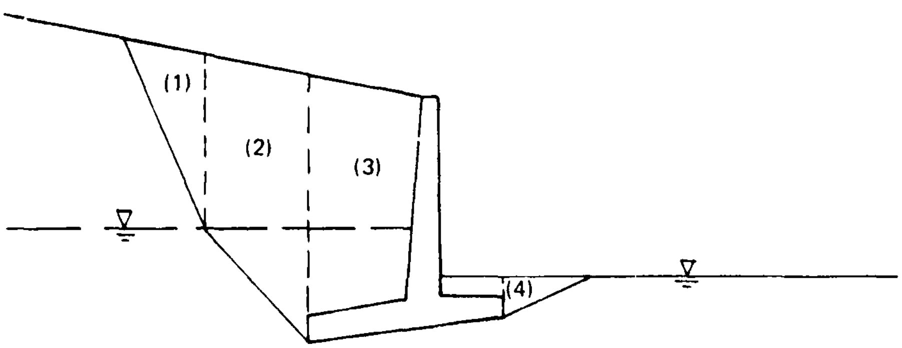


Figure B1. Retaining wall for Appendix B, Problem 1

8. The assumed wedge failure mechanism is shown below. This is followed by calculations of seepage pressures, by the line-of-creep method, at wedge vertex elevations.

Failure Mechanism

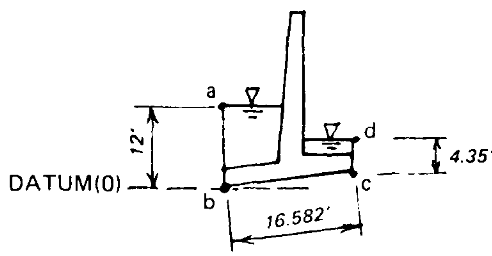


Seepage Pressures

Gradient: $i = \frac{\Delta H}{L}$

$$= \frac{(112' - 106')}{(12' + 16.582' + 4.35')}$$

$$= 0.18219$$



$$\text{Pressure} = P = -\gamma_{water}\left[\begin{matrix}\text{headwater}\\ \text{head}\end{matrix} - \begin{matrix}\text{point}\\ \text{elevation}\end{matrix} - \text{gradient}\begin{pmatrix}\text{path}\\ \text{length}\end{pmatrix}\right]$$

$P_a = 0.00$

$P_b = \gamma_w[12' - 0' - (i)(12')] = 0.613$ ksf

$P_c = \gamma_w[12' - 1.65' - (i)(12 + 16.582)] = 0.321$ ksf

$P_d = 0.00$

Hand Solution--Problem 1

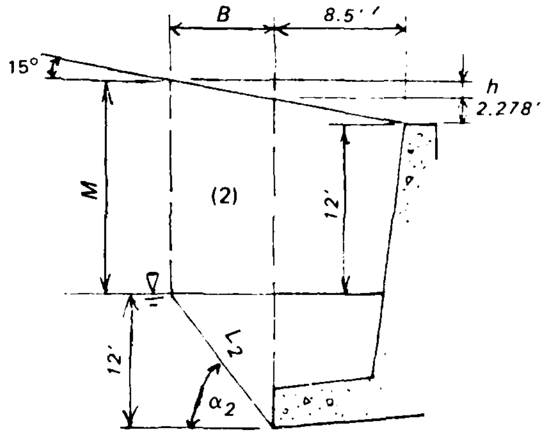
Trial 1

9. For the first iteration, use a safety factor of 1.00 and begin with wedge 2. The geometry of wedge 1 cannot be found until geometry of wedge 2 is known.

$\boxed{FS = 1.0}$

Wedge 2

Trial failure angle:



$$\alpha_2 = -\left(45 + \frac{\phi_e}{2}\right)$$

$$\tan \phi_d = \frac{\tan \phi_2}{FS} = \frac{\tan 30°}{1.0}$$

$$\phi_d = 30°$$

$$\alpha_2 = -\left(45 + \frac{30}{2}\right) = -60°$$

$$\sin \alpha_2 = -0.8660$$

$$\cos \alpha_2 = -0.5000$$

(Continued)

(Sheet 1 of 20)

FS = 1

Wedge 2

$$\text{Width, } B_2 = \frac{12}{\tan 60°} = 6.928'$$

$$\text{Submerged length, } L_2 = \frac{12}{\sin 60°} = 13.857'$$

$$h = B \tan 15° = 1.856'$$

$$M = 12 + h = 14.134'$$

$$\text{Weight, } W_2 = 0.125 \text{ kcf}\left[\frac{1}{2}(6.928 \times 12)\right] + 0.120 \text{ kcf}\left[\frac{1}{2}(14.134 + 12.278) \times 6.928\right]$$

$$W_2 = 16.175^k$$

$$\text{Uplift, } U_2 = \frac{1}{2}(0 + 0.613)\text{ksf}(13.857') = 4.247^k$$

No external loads: $V_2 = H_{L_2} = H_{R_2} = 0$

a. Calculate the net force on the wedge using the general wedge equation.

$$P_1 - P_2 = \frac{[(16.175^k)0.5000 - 4.247^k]\frac{\tan 30°}{1.0} + (16.175^k)(-0.8660)}{0.5000 - (-0.8660)\frac{\tan 30°}{1.0}}$$

$$\boxed{P_1 - P_2 = -11.790^k}$$

(Continued)

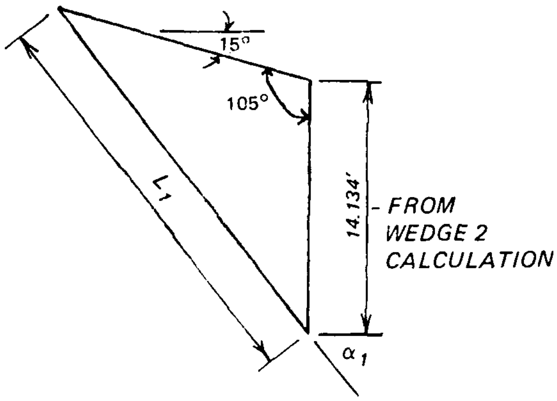
Hand Solution (Continued)

FS = 1.0

Wedge 1

Failure angle, α_1 :

b. The equations shown below are taken from the draft EM, "Retaining and Flood Walls."



For the case of a cohesionless backfill with an unbroken top surface, the failure angle can be approximated by...

$$\alpha_{active} = \tan^{-1}\left(\frac{-c_1 - \sqrt{c_1^2 + 4c_2}}{2}\right),$$

where

$$c_1 = 2 \tan \phi_d$$

$$c_2 = \frac{\tan \phi_d(1 - \tan \phi_d \tan \beta) - \tan \beta}{\tan \phi_d}$$

β = slope of backfill surface

ϕ_d = developed (effective) friction angle

(Continued)

(Sheet 3 of 20)

FS = 1.0 Wedge 1

c. To calculate a trial failure angle, use the following:

$$\phi_d = \tan^{-1}\left(\frac{\tan\phi}{FS}\right) = 30°$$

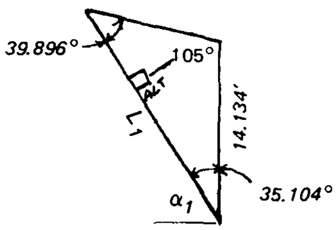
$$\beta = 15°$$

$$c_1 = 1.1547$$

$$c_2 = 0.3812$$

$$\sin\alpha_1 = -0.818$$

$$\therefore\ \alpha_1 = -54.896° \qquad \cos\alpha_1 = 0.575$$



$$\frac{\sin 105°}{L_1} = \frac{\sin 39.896°}{14.134'}$$

$$L_1 = 21.285'$$

altitude (from 105° to L_1) = 14.134' (sin 35.104°) = 8.128'

weight, $W_1 = \frac{1}{2}(21.285' \times 8.128')(0.120\ \text{kcf}) = 10.380^k$

uplift, $U_1 = 0$

forces, $V_1 = 0$

$H_{L_1} = H_{R_1} = 0$

Net force:

$$P_o - P_1 = \frac{\left[(10.380^k)\cos\alpha_1\right]\frac{\tan\phi_1}{FS} + (10.380)\sin\alpha_1}{\cos\alpha_1 - \sin\alpha_1\left(\frac{\tan\phi}{FS}\right)}$$

$$\boxed{P_o - P_1 = -4.817^k}$$

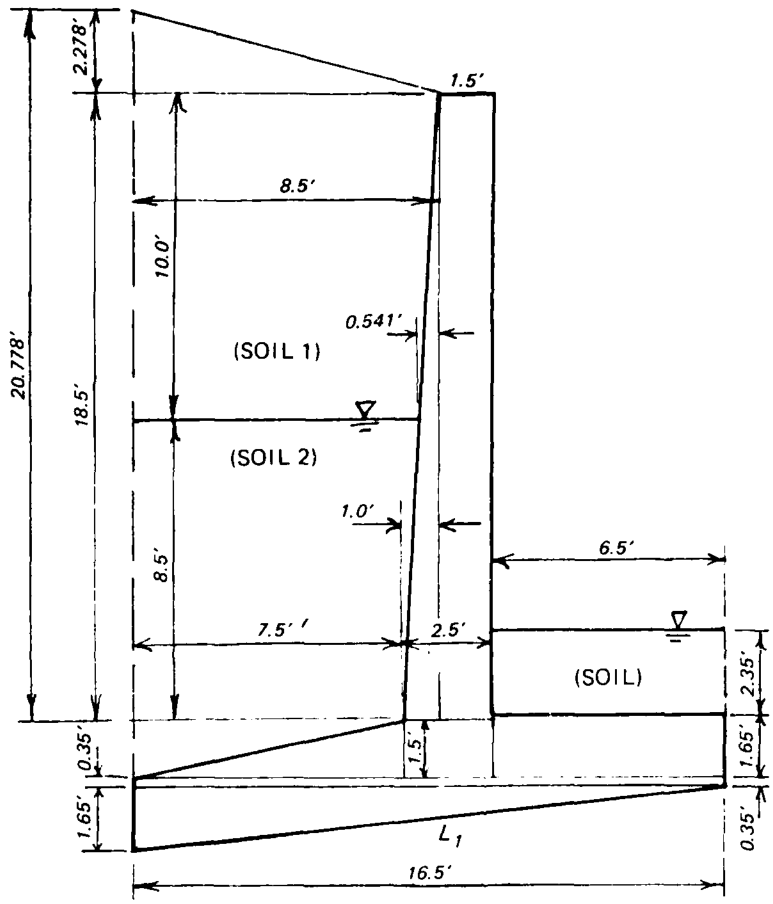
(Continued)

(Sheet 4 of 20)

FS = 1.0

Wedge 3

Structural Wedge



$$\alpha_3 = \tan^{-1}\left(\frac{1.65}{16.5}\right) = 5.711°$$

$\cos \alpha_1 = 0.995$

$\sin \alpha_1 = 0.100$

Weight of concrete, W_c :

$$W_c = 0.150 \text{ kcf}\left[\frac{1}{2}(1.65 \times 16.5) + (0.35 \times 16.5) + \frac{1}{2}(7.5 \times 1.5) + (1.5 \times 2.5) + (1.65 \times 6.5) + \frac{1}{2}(1 \times 18.5) + (1.5 \times 18.5)\right]$$

$$W_c = 11.473^k$$

(Continued)

FS = 1.0
Wedge 3

$$L_3 = \sqrt{1.65^2 + 16.5^2} = 16.582'$$

$$U_3 = \frac{1}{2}(0.613 + 0.321)\text{kcf}(16.582') = 7.744^k$$

$$V_3 = \text{soil weight}$$

$$= 0.120 \text{ kcf}\left[\frac{1}{2}(2.278 \times 8.5) + \frac{1}{2}(10' \times 0.541') + (10 \times 7.959)\right] + 0.125 \text{ kcf}\left\{(7.5 \times 8.5) + \frac{1}{2}[8.5 \times (1 - 0.541)] + \frac{1}{2}(1.5 \times 7.5)\right\} + 0.125 \text{ kcf}(2.35 \times 6.5)$$

$$V_3 = 21.862^k$$

$$H_{L_3} = H_{R_3} = 0$$

Net force:

$$P_2 - P_3 = \frac{[(11.473 + 21.862)\cos\alpha_3 - 7.744]\dfrac{\tan 30°}{1.0} + (11.473 + 21.862)\sin\alpha_3}{\cos\alpha_3 - \sin\alpha_3\dfrac{\tan 30°}{1.0}}$$

$$\boxed{P_2 - P_3 = 19.218^k}$$

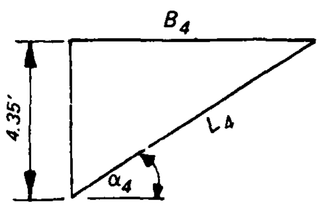
(Continued)

(Sheet 6 of 20)

Hand Solution (Continued)

$\boxed{FS = 1.0}$

Wedge 4



$$\alpha_4 = 45 - \frac{\phi_d}{2} = 30°$$

$$\cos \alpha_4 = 0.866$$

$$\sin \alpha_4 = 0.5$$

submerged length, $L_4 = \dfrac{4.35}{\sin 30} = 8.700'$

width, $B_4 = (\cos 30°)\ 8.7' = 7.534'$

weight, $W_4 = 0.125\ \text{kcf}\left[\frac{1}{2}\ (4.35 \times 7.534)\right] = 2.048^k$

uplift, $U_4 = \frac{1}{2}\ (0.321 + 0.)\text{ksf}\ (8.7') = 1.396^k$

$$V_4 = H_{L_4} = H_{R_4} = 0$$

Net force:

$$P_3 - P_4 = \frac{[(2.048^k)0.866 - 1.396]\ \frac{\tan 30°}{1.0} + (2.048)(0.5)}{0.866 - 0.5\left(\frac{\tan 30°}{1.0}\right)}$$

$$\boxed{P_3 - P_4 = 2.151^k}$$

(Continued)

(Sheet 7 of 26)

FS = 1.0 Wedge 4

d. The sum of all the net forces on the system is as follows:

$$\sum(P_{i-1} - P_i) = -11.790^k - 4.817^k + 19.218^k + 2.151^k$$

$$= 4.762^k$$

e. This sum of forces greater than zero means that the safety factor is greater than 1.0.

Trial 2

10. For the second iteration, use a trial FS equal to 2.0.

FS = 2.0

Wedge 2

$$\alpha_2 = -\left(45 + \frac{\phi_d}{2}\right) \qquad \phi_d = \tan^{-1}\left(\frac{\tan 30°}{2.0}\right) = 16.102°$$

$$= -53.051°$$

$$\sin \alpha_2 = -0.799$$

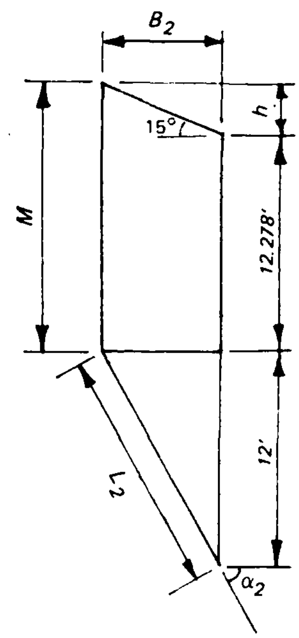
$$\cos \alpha_2 = 0.601$$

(Continued)

(Sheet 8 of 20)

Hand Solution (Continued)

FS = 2.0
Wedge 2



$$B_2 = \frac{12'}{\tan \alpha_2} = 9.026'$$

$$L_2 = \frac{12'}{\sin \alpha_2} = 15.016'$$

$$h = (\tan 15°)\ 9.026' = 2.419'$$

$$M = 12.278 + 2.419 = 14.697'$$

Weight, $W_2 = 0.120 \text{ kcf} \left[\frac{1}{2}(14.697 + 12.278)(9.026)\right] + 0.125 \text{ kcf} \left[\frac{1}{2}(9.026 \times 12)\right]$

$$W_2 = 21.513^k$$

Uplift, $U_2 = \frac{1}{2}(0 + 0.613)\text{ksf}\ (15.016') = 4.602^k$

$$V_2 = 0$$

$$H_2 = 0$$

Net force:

$$P_1 - P_2 = \frac{[(21.513)0.601 - 4.602]\ \frac{\tan 30°}{2.0} + (21.513)(-0.799)}{0.601 - (-0.799)\ \frac{\tan 30°}{2.0}}$$

$$\boxed{P_1 - P_2 = -17.778^k}$$

(Continued)

(Sheet 9 of 20)

$\boxed{FS = 2.0}$

Wedge 1

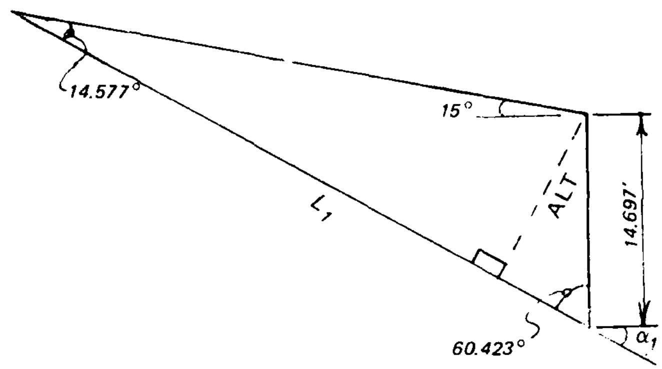
$\phi_e = 16.102°$

$\beta = 15°$

$c_1 = 0.57735$

$c_2 = -0.00556$

$\alpha_1 = -29.577°$



$\sin \alpha_1 = -0.494$

$\cos \alpha_1 = 0.870$

$$\frac{\sin 105°}{L_1} = \frac{\sin 14.577°}{14.697'} \; , \quad L_1 = 56.406'$$

altitude = (sin 60.423)14.697 = 12.782'

$$W_1 = \frac{1}{2}(12.782 \times 56.406)(0.120 \text{ kcf}) = 43.259^k$$

$U_1 = 0$

$V_1 = 0$

$H_{L_1} = H_{R_1} = 0$

Net force:

$$P_o - P_1 = \frac{[(43.259)0.870]\frac{\tan 30°}{2.0} + (43.259)(-0.494)}{0.870 - (-0.494)\frac{\tan 30°}{2.0}}$$

$$\boxed{P_o - P_1 = -10.375^k}$$

(Continued)

(Sheet 10 of 20)

Hand Solution (Continued)

$\boxed{FS = 2.0}$

Wedge 3, Structure

a. All forces on the structural wedge are the same as those previously calculated for the structural wedge. The only change in the net force calculation is due to the safety factor.

$$\therefore P_2 - P_3 = \frac{[(33.335^k)0.995 - 7.744]\ \frac{\tan 30°}{2.0} + (33.335)0.100}{0.995 - 0.100\left(\frac{\tan 30°}{2.0}\right)}$$

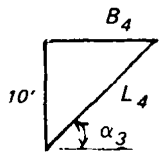
$$\boxed{P_2 - P_3 = 11.047^k}$$

Wedge 4

$$\alpha_4 = \left(45 - \frac{16.102}{2}\right) = 36.949°$$

$$\sin \alpha_4 = 0.601$$

$$\cos \alpha_4 = 0.799$$



$$L_4 = \frac{4.35}{\sin \alpha_4} = 7.237'$$

$$B_4 = (\cos \alpha_4)7.237' = 5.784'$$

$$W_4 = \frac{1}{2}\ (5.784 \times 4.35)(0.125\ \text{kcf}) = 1.572^k$$

$$U_4 = \frac{1}{2}\ (0.321\ \text{ksf})7.237' = 1.162^k$$

$$V_4 = 0$$

$$H_4 = 0$$

Net force:

$$P_3 - P_4 = \frac{[(1.572^k)0.799 - 1.162^k]\ \frac{\tan 30°}{2.0} + (1.572^k)(0.601)}{0.799 - 0.601\left(\frac{\tan 30°}{2.0}\right)}$$

$$\boxed{P_3 - P_4 = 1.554^k}$$

(Continued)

(Sheet 11 of 20)

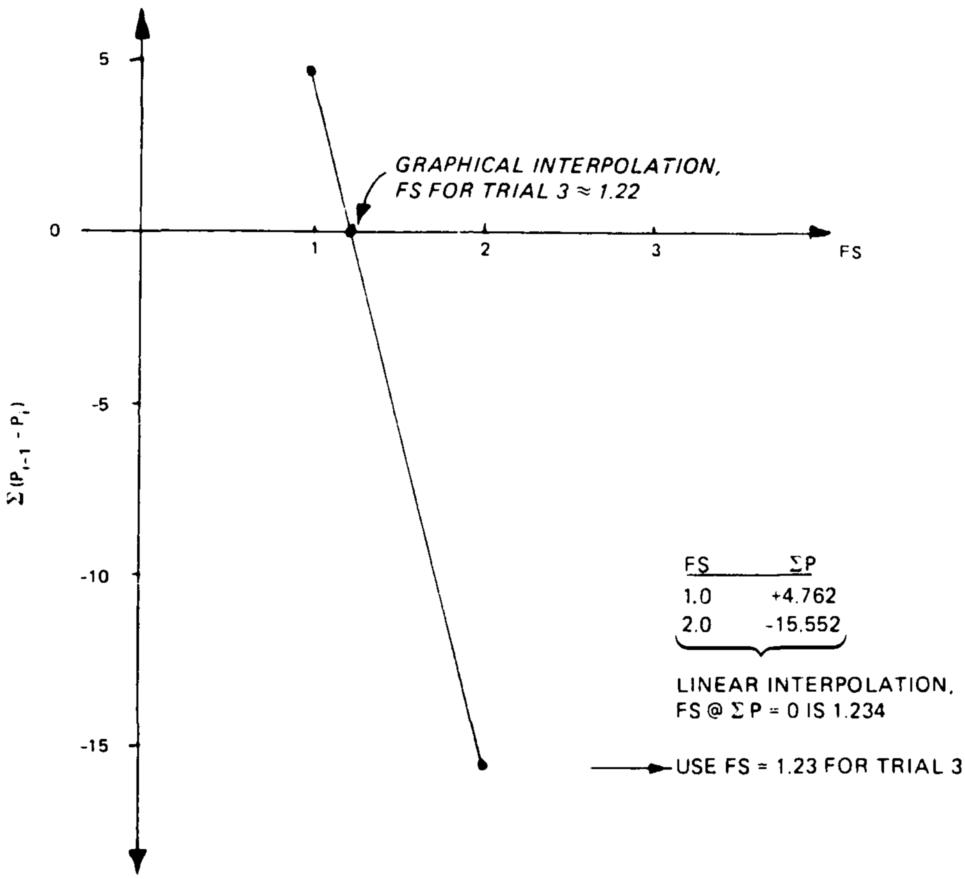
Hand Solution (Continued)

Trial 2, FS = 2.0 , sum of forces:

$$\sum(P_{i-1} - P_i) = -17.778^k - 10.375^k + 11.047^k + 1.554^k$$

$$= -15.552^k$$

b. This negative sum of forces indicates the safety factor is less than 2.0.



c. The safety factor for Trial 3 is linearly interpolated from the results of Trials 1 and 2.

(Continued)

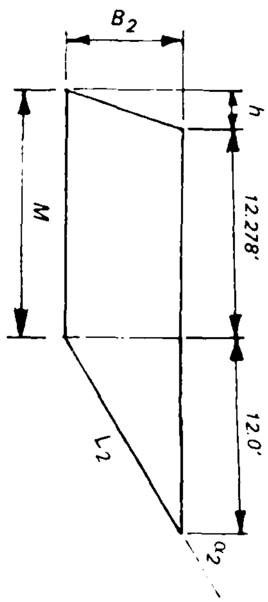
(Sheet 12 of 20)

Trial 3

11. For the third iteration, a trial FS equal to 1.23 is used.

$\boxed{FS = 1.23}$

Wedge 2



$$\phi_d = \frac{\tan 30°}{1.23} = 25.145°$$

$$\alpha_2 = -\left(45 + \frac{\phi_d}{2}\right) = -57.572°$$

$$\sin \alpha_2 = -0.844$$

$$\cos \alpha_2 = 0.536$$

$$L_2 = \frac{12}{\sin \alpha_2} = 14.218'$$

$$B_2 = (\cos \alpha_2)14.218' = 7.621'$$
$$h = (\tan 15°)7.621' = 2.042'$$
$$M = 12.278' + 2.042' = 14.320'$$

$$W_2 = \frac{1}{2}\ (14.320 + 12.278)(7.621)(0.120\ \text{kcf})$$
$$+ \frac{1}{2}\ (12 \times 7.621)(0.125\ \text{kcf}) = 17.878$$
$$U_2 = \frac{1}{2}\ (0.613\ \text{ksf})(14.218') = 4.358^k$$

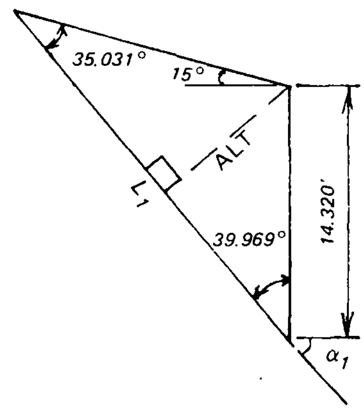
$$P_1 - P_2 = \frac{[(17.878^k)0.536 - 4.358]\ \frac{\tan 30°}{1.23} + (17.878)(-0.844)}{0.536 - (-0.844)\left(\frac{\tan 30°}{1.23}\right)}$$

$$\boxed{P_1 - P_2 = -13.556^k}$$

(Continued)

(Sheet 13 of 20)

Wedge 1



ϕ_d = 25.145°

β = 15°

c_1 = 0.93878

c_2 = 0.30338

α_1 = -50.031°

$$\sin \alpha_1 = -0.766$$
$$\cos \alpha_1 = 0.642$$

$$L_1 = (\sin 105°)\ \frac{14.320'}{\sin 35.031°} = 24.097'$$

$$\text{alt.} = (\sin 39.969°)14.320' = 9.199'$$

$$W_1 = \frac{1}{2}\ (9.199 \times 24.097)(0.120\ \text{kcf}) = 13.300^k$$

$$P_o - P_1 = \frac{[(13.3^k)(0.642)]\ \dfrac{\tan 30°}{1.23} + (13.3)(-0.766)}{0.642 - (-0.766)\left(\dfrac{\tan 30°}{1.23}\right)}$$

$$\boxed{P_o - P_1 = -6.170^k}$$

(Continued)

(Sheet 14 of 20)

Hand Solution (Continued)

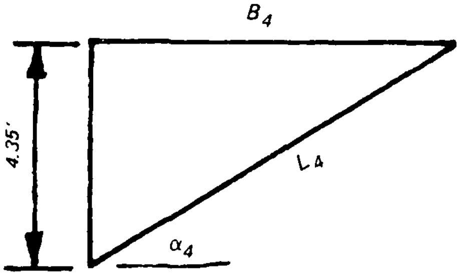
$\boxed{FS = 1.23}$

Wedge 3, Structure

$$P_2 - P_3 = \frac{[(33.335)(0.995) - 7.744]\,\frac{\tan 30°}{1.23} + (33.335)0.100}{0.995 - 0.100\left(\frac{\tan 30°}{1.23}\right)}$$

$$P_2 - P_3 = 16.104^k$$

Wedge 4



$$\phi_d = 25.145°$$

$$\alpha_4 = 45 - \frac{\phi_d}{2} = 32.428°$$

$$\sin \alpha_4 = 0.536$$

$$\cos \alpha_4 = 0.844$$

$$B_4 = \frac{4.35}{\tan \alpha_4} = 6.847$$

$$L_4 = \frac{4.35}{\sin \alpha_4} = 8.116$$

$$W_4 = \frac{1}{2}\,(4.35 \times 6.847)(0.125\ \text{kcf}) = 1.862^k$$

$$U_4 = \frac{1}{2}(0.321)(8.116') = 1.303^k$$

$$V_4 = 0$$

$$H_{L_4} = H_{R_4} = 0$$

Net force:

$$P_3 - P_4 = \frac{[(1.862)0.844 - 1.303]\,\frac{\tan 30°}{1.23} + (1.862)(0.536)}{0.844 - 0.536\left(\frac{\tan 30°}{1.23}\right)}$$

$$\boxed{P_3 - P_4 = 1.897^k}$$

(Continued)

(Sheet 15 of 20)

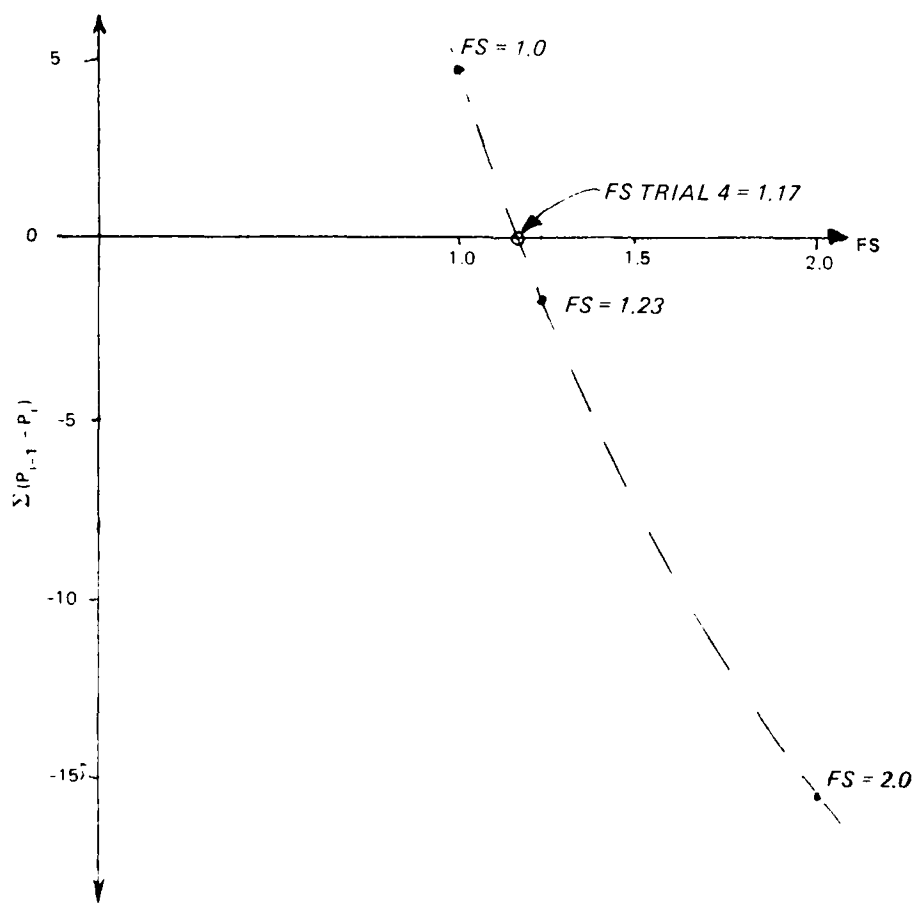
Hand Solution (Continued)

a. The sum of net forces for FS = 1.23 is as follows:

$$\sum(P_{i-1} - P_i) = -13.556^k - 6.170^k + 16.104^k + 1.897^k = -1.725^k$$

∴ FS is less than 1.23.

b. Interpolate a new trial safety factor from a curve drawn through the three points already obtained.



(Continued)

(Sheet 16 of 20)

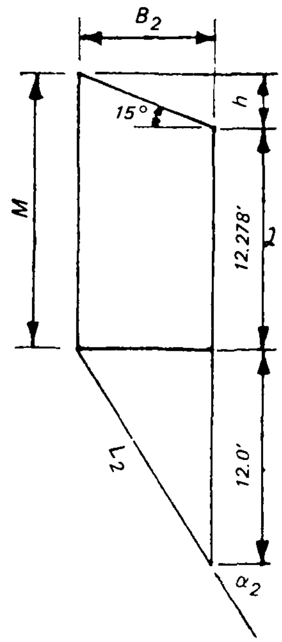
Hand Solution (Continued)

Trial 4

12. For the fourth iteration, a trial FS equal to 1.17 is used.

$\boxed{FS = 1.17}$

Wedge 2



$$\phi_d = \tan^{-1}\left(\frac{\tan 30°}{1.17}\right) = 26.265°$$

$$\alpha_2 = -\left(45 + \frac{\phi_d}{2}\right) = -58.132°$$

$$\sin \alpha_2 = -0.849$$

$$\cos \alpha_2 = 0.528$$

$$B_2 = \frac{12}{\tan \alpha_2} = 7.460'$$

$$h = 7.460 \tan 15° = 1.999'$$

$$M = 1.999 + 12.278 = 14.277'$$

$$L_2 = \frac{12}{\sin \alpha_2} = 14.134'$$

$$W_2 = \left[\frac{1}{2}(14.134 + 12.278)(7.460')\right](0.120 \text{ kcf}) + \left[\frac{1}{2}(7.460 \times 12)\right](0.125 \text{ kcf}) = 17.417^k$$

$$U_2 = \frac{1}{2}(0. + 0.613)\text{ksf}\ (14.134') = 4.332^k$$

$$V_2 = 0$$

$$H_{L_2} = H_{R_2} = 0$$

Net force:

$$P_1 - P_2 = \frac{\underline{(17.417)0.528 - 4.332}\ \frac{\tan 30°}{1.17} + (17.417)(-0.849)}{0.528 - (-0.849)\ \frac{\tan 30°}{1.17}}$$

$$\boxed{P_1 - P_2 = -13.081^k}$$

(Continued)

(Sheet 17 of 20)

$\boxed{FS = 1.17}$

Wedge 1

$$\phi_d = 26.265°$$

$$\beta = 15°$$

$$c_1 = 2 \tan \phi_d = 0.98692$$

$$c_2 = \frac{\tan \phi_d(1 - \tan \phi_d \tan \beta) - \tan \beta}{\tan \phi_d}$$

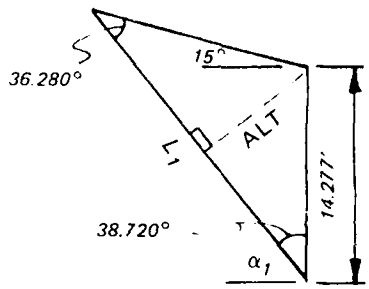
$$= 0.32478$$

$$\alpha_1 = \tan^{-1}\left(\frac{-c_1 - \sqrt{c_1^2 + 4c_2}}{2}\right)$$

$$\alpha_1 = 51.280°$$

$$\sin \alpha_1 = -0.780$$

$$\cos \alpha_1 = 0.626$$



$$L_1 = \frac{\sin 105°}{\sin 36.28°} (14.277') = 23.305'$$

$$\text{alt.} = 14.277(\sin 38.720°) = 8.930'$$

$$W_1 = \frac{1}{2} (23.305' \times 8.93')(0.120 \text{ kcf}) = 12.487^k$$

$$U_1 = 0$$

$$V_1 = 0$$

$$H_{L_1} = H_{R_1} = 0$$

Net force:

$$P_o - P_1 = \frac{[(12.487)0.626] \frac{\tan 30°}{1.17} + (12.487)(-0.780)}{0.626 - (-0.780) \frac{\tan 30°}{1.17}}$$

$$\boxed{P_o - P_1 = -5.819^k}$$

(Continued)

(Sheet 18 of 20)

Hand Solution (Continued)

$\boxed{FS = 1.17}$

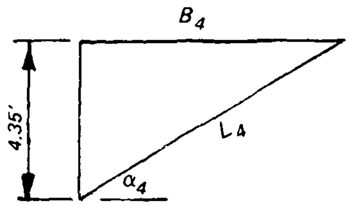
Wedge 3, Structure

$$P_2 - P_3 = \frac{(25.424)\ \dfrac{\tan 30°}{1.17} + 3.334}{0.995 - 0.1\left(\dfrac{\tan 30°}{1.17}\right)}$$

$$\boxed{P_2 - P_3 = 16.792^k}$$

Wedge 4

$$\alpha_4 = \left(45 - \frac{\phi_d}{2}\right), \quad \phi_d = 26.265°$$



$$= 31.868°$$

$$\sin \alpha_4 = 0.528$$

$$\cos \alpha_4 = 0.849$$

$$L_4 = \frac{4.35}{\sin \alpha_4} = 8.239'$$

$$B_4 = 8.239 \cos \alpha_4 = 6.995'$$

$$W_4 = \frac{1}{2}\ (4.35' \times 6.995')0.125 \text{ kcf} = 1.902^k$$

$$U_4 = \frac{1}{2}\ (0.321 \text{ ksf})8.239' = 1.322^k$$

Net force:

$$P_3 - P_4 = \frac{[(1.902^k)0.849 - 1.322]\ \dfrac{\tan 30°}{1.17} + (1.902)0.528}{0.849 - 0.528\left(\dfrac{\tan 30°}{1.17}\right)}$$

$$\boxed{P_3 - P_4 = 1.952^k}$$

(Continued)

(Sheet 19 of 20)

Hand Solution (Concluded)

The sum of net forces for FS = 1.17 is as follows:

$$\sum (P_{i-1}) - P_i) = -13.081^k - 5.819^k + 16.792^k + 1.952^k$$

$$= -0.156^k$$

13. The actual FS is slightly less than 1.17, approximately 1.15.

14. CSLIDE is used to analyze this problem. The CSLIDE results are compared with the long-hand calculations.

(Sheet 20 of 20)

15. The data file for the CSLIDE analysis of Problem 1 is shown below.

```
 OLD,RETWL
/ LIST
00100 TITL INCLINED BACKFILL
00110 STRU 8 .15
00120 100 100 100 102
00130 107.5 103.5 108.5 122
00140 110 122 110 103.65
00150 116.5 103.65 116.5 101.65
00160 SOLT 1 1 30 0 .12 122
00170 -100 177.8674
00180 SOLT 2 1 30 0 .125 112
00190 -100 112
00200 SOST 30 0
00210 SORT 1 1 30 0 .125 106
00220 200 106
00230 METH 2
00240 WATR 112 106 .0625
00250 END
/
```

16. The echoprint of the input data to Problem 1 is shown on the following pages.

```
 IS INPUT FROM TERMINAL OR FILE?
 ENTER "T" OR "F".
? F

 ENTER DATA FILE NAME (MAXIMUM 7 CHARACTERS)
? RETWL

INPUT COMPLETE, DO YOU WANT TO EDIT DATA?
ENTER 'Y' OR 'N'
? N

 DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
 TERMINAL, FILE, BOTH, OR NEITHER?
 ENTER "T", "F", "B" OR "N"
? T


------------------------------
  PROGRAM CSLIDE - ECHOPRINT
------------------------------

DATE: 86/06/11.                         TIME: 14.08.25.

INCLINED BACKFILL


MULTI  FAILURE PLANE ANALYSIS

SEEPAGE FORCE BY LINE OF CREEP, GRADIENT
COMPUTED USING SHORTEST SEEPAGE PATH .


NO OF CORNERS IN STRUCTURE ----------         8
DENSITY OF CONCRETE -----------------      .1500(KCF)
DENSITY OF WATER --------------------      .0625(KCF)
WATER LEVEL LEFT SIDE ---------------    112.00(FT)
WATER LEVEL RIGHT SIDE --------------    106.00(FT)
NO  OF SOIL LAYERS LEFT SIDE --------         2
NO  OF SOIL LAYERS RIGHT SIDE -------         1
```

STRUCTURE INFORMATION

POINT	X-COORD	Y-COORD
1	100.00	100.00
2	100.00	102.00
3	107.50	103.50
4	108.50	122.00
5	110.00	122.00
6	110.00	103.65
7	116.50	103.65
8	116.50	101.65

LEFTSIDE SOIL DATA

LAYER NO	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	.120	122.00
2	30.00	.0000	.125	112.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	-100.00	177.87
2	-100.00	112.00

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 30.00
COHESION --------------- .0000

RIGHTSIDE SOIL DATA

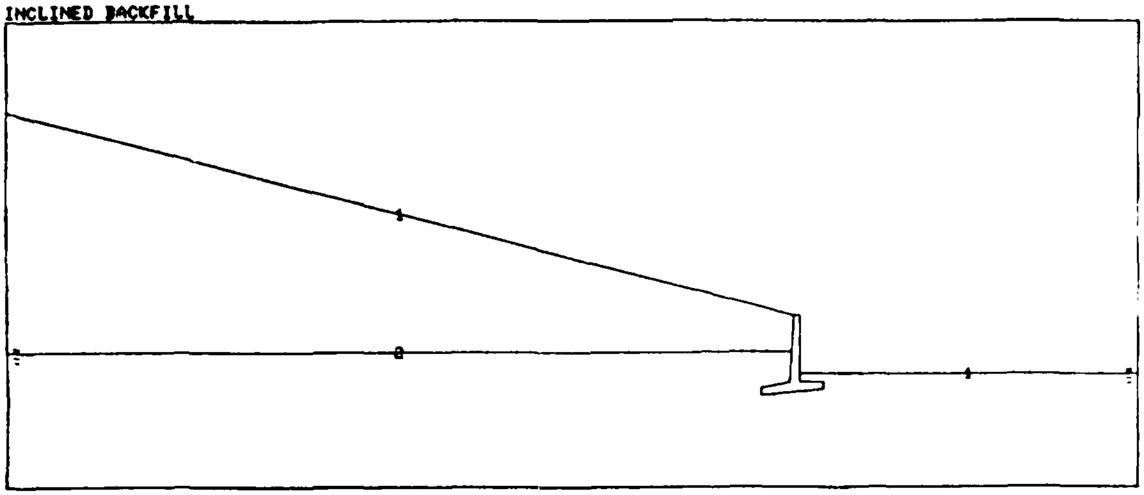
LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	30.00	.0000	125	106.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	200.00	106.00

DO YOU WANT TO PLOT THE INPUT DATA. ENTER 'Y' OR 'N'.
? Y

17. A plot of the input data is shown, followed by the final results of this analysis.

INCLINED BACKFILL



Plot of input data

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/06/11. TIME: 14.11.30

INCLINED BACKFILL

MULTIPLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	.000
2	.000	.000	.000
3	.000	.000	21.863
4	.000	.000	.000

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	000	000
2	000	613

STRUCTURAL WEDGE

X-COORD (FT)	PRESSURE (KSF)
100 00	613
116.50	321

RIGHTSIDE WEDGES

WEDGE NO	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
4	000	321

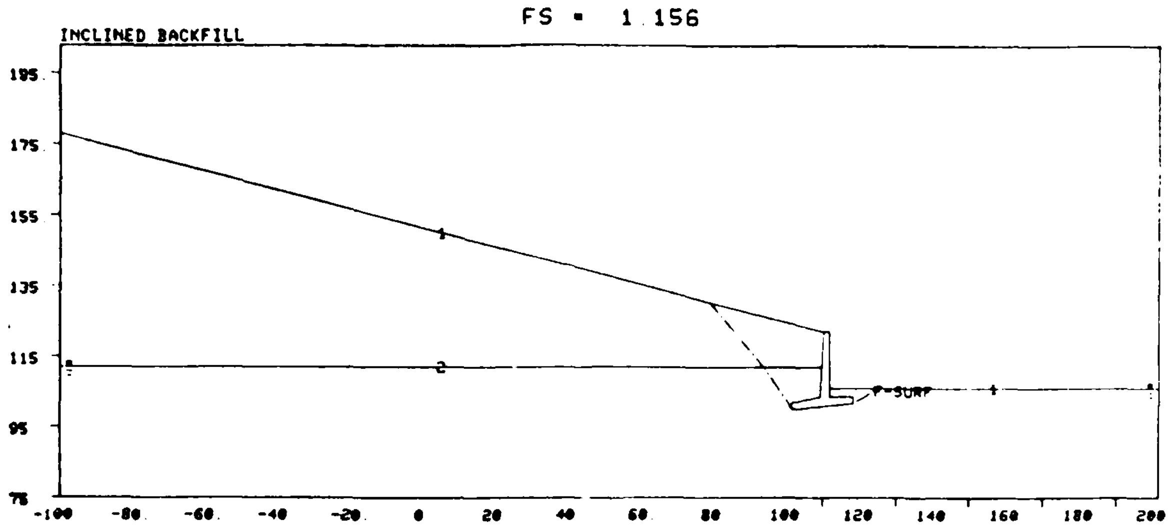
WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-51.6	23 338	12.530	000	000
2	-56.5	14.390	18.673	14.390	4 413
3	5 711	16 582	11.473	16 582	7 750
4	31.7	8.278	1.915	8 278	1 330

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-5.860
2	-13.041
3	16.937
4	1.964

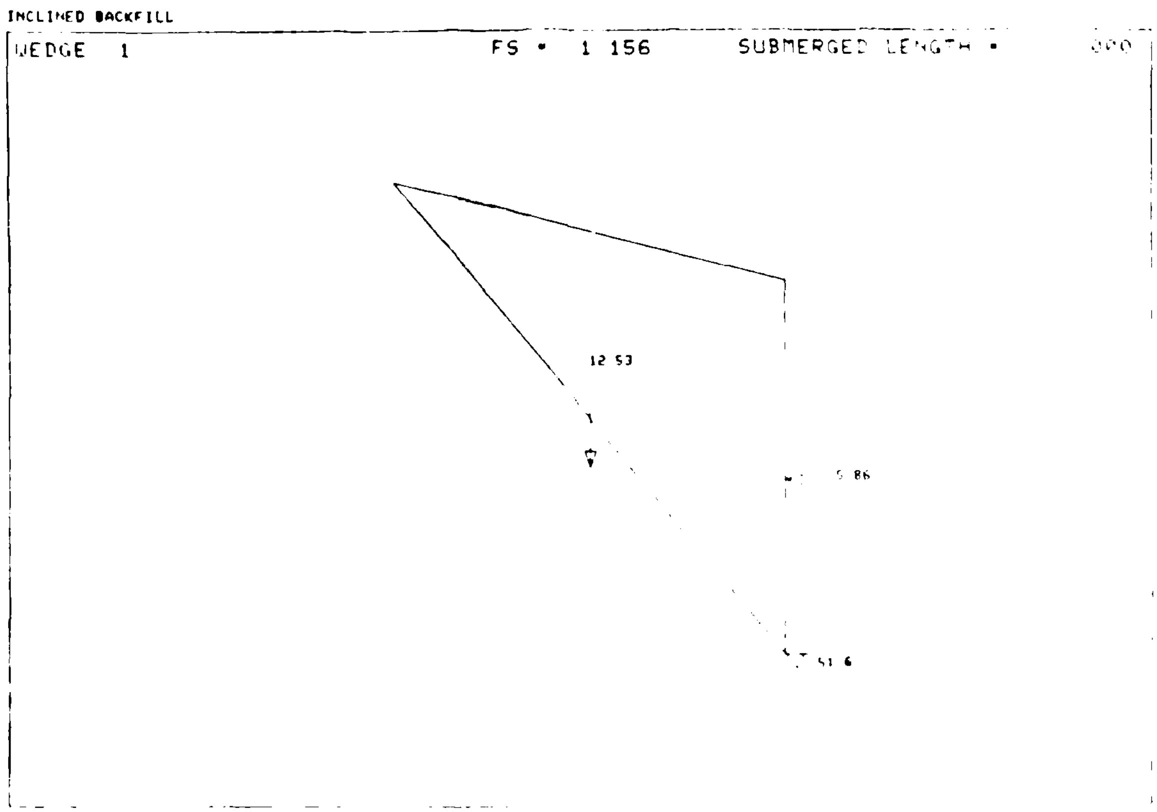
SUM OF FORCES ON SYSTEM ---- 000

FACTOR OF SAFETY ----------- 1 156

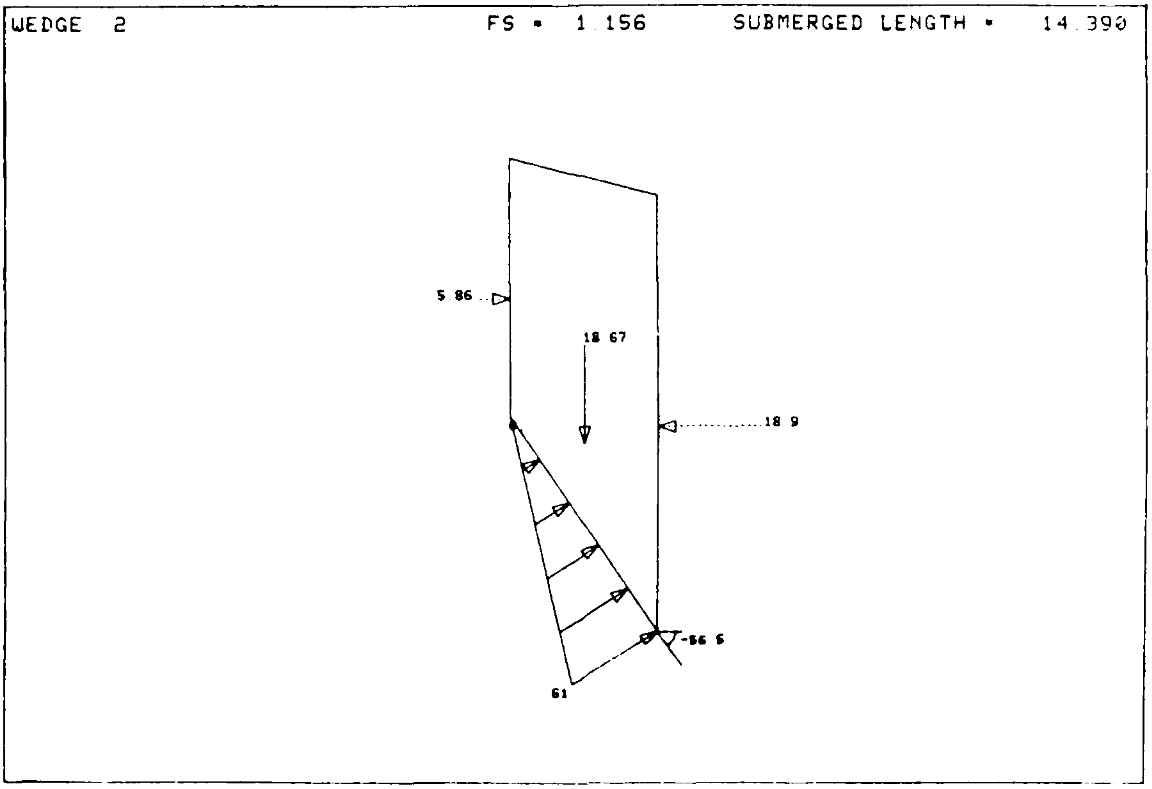
18. The plot of the failure surface, wedges 1, 2, structural wedge, and 4 are shown respectively on the following pages.



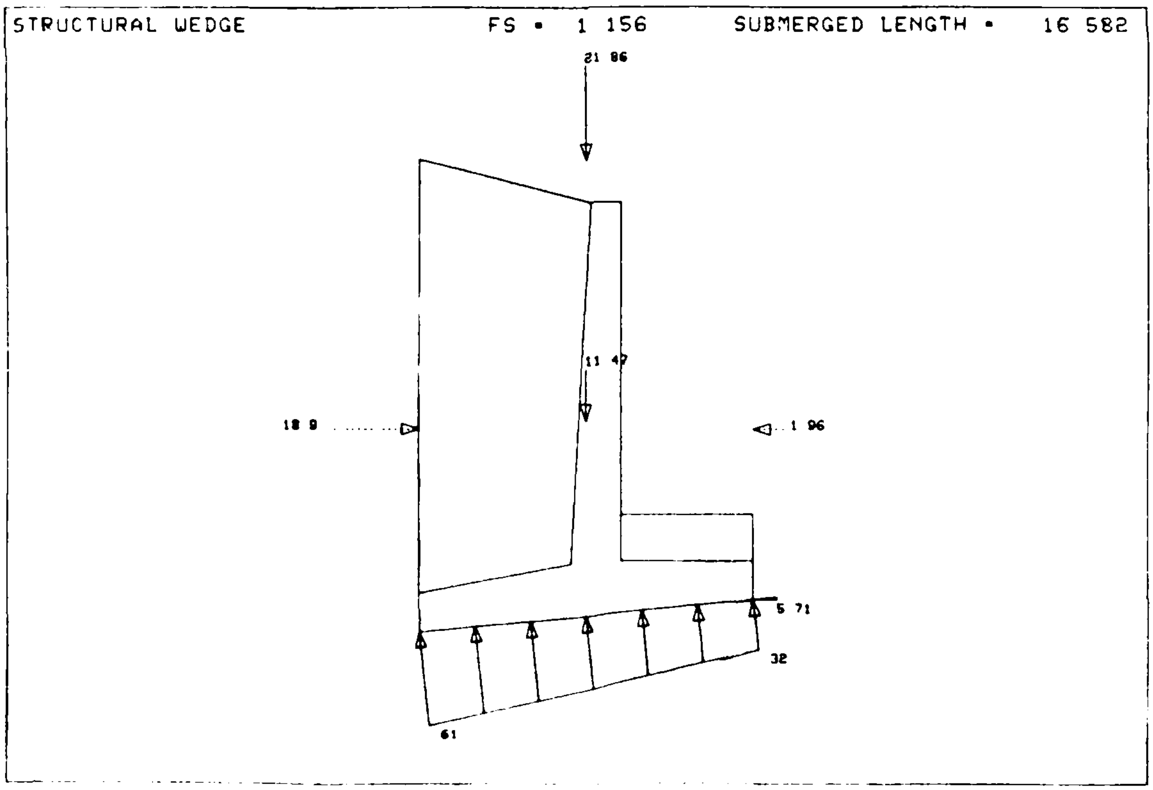
Plot of Failure Surface, Problem B1



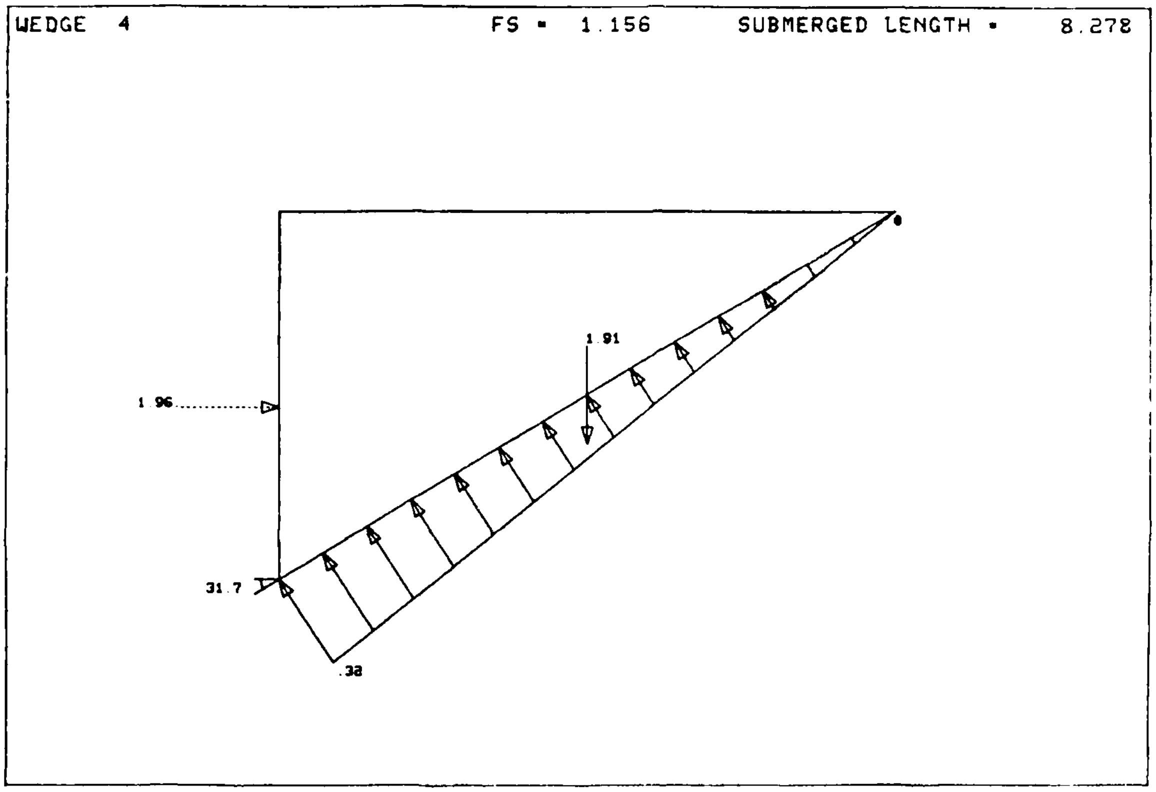
INCLINED BACKFILL



INCLINED BACKFILL



INCLINED BACKFILL



19. A comparison of the hand and the CSLIDE solutions is shown in the following tabulation.

Comparison of Results

Last iteration of hand solution, FS = 1.17

Versus

CSLIDE equilibrium solution, FS = 1.156

Wedge No.	Horizontal Load (kips) CSLIDE	Horizontal Load (kips) Hand	Vertical Load (kips) CSLIDE	Vertical Load (kips) Hand	Failure Angle (deg) CSLIDE	Failure Angle (deg) Hand
1	0	0	0	0	-51.6	-51.280
2	0	0	0	0	-56.5	-58.132
3	0	0	21.863	21.862	5.711	5.711
4	0	0	0	0	31.7	31.868

Wedge No.	Wedge Weight (kips) CSLIDE	Wedge Weight (kips) Hand	Uplift Force (kips) CSLIDE	Uplift Force (kips) Hand	Net Force (kips) CSLIDE	Net Force (kips) Hand
1	12.530	12.487	0	0	-5.860	-5.819
2	18.673	17.417	4.413	4.332	-13.041	-13.081
3	11.473	11.473	7.750	7.744	16.937	16.792
4	1.915	1.902	1.330	1.322	1.964	1.952

	Sum of Forces (kips)	Safety Factor
CSLIDE	0.000	1.156
Hand	-0.156	1.17

Problem 2

20. This long-hand solution solves for the sliding safety factor of the dam shown in Figure B2.

21. Trial failure angles are calculated from $(45 \pm \phi_d/2)$. Seepage pressures are calculated from the line-of-creep method, using the shortest seepage path.

22. The value of the friction angle of soil beneath the structure is decreased to account for the smooth concrete base.

$$\phi_{\text{structural wedge}} = \delta \simeq \frac{2}{3}\,\phi_{\text{ soil below structure}}$$

23. Iterations with different trial safety factors are continued until a sum of net forces is equal or close to zero. CSLIDE is then used to analyze this problem. The safety factor obtained in CSLIDE is used in one final hand iteration to check results. All results are compared in a summary table.

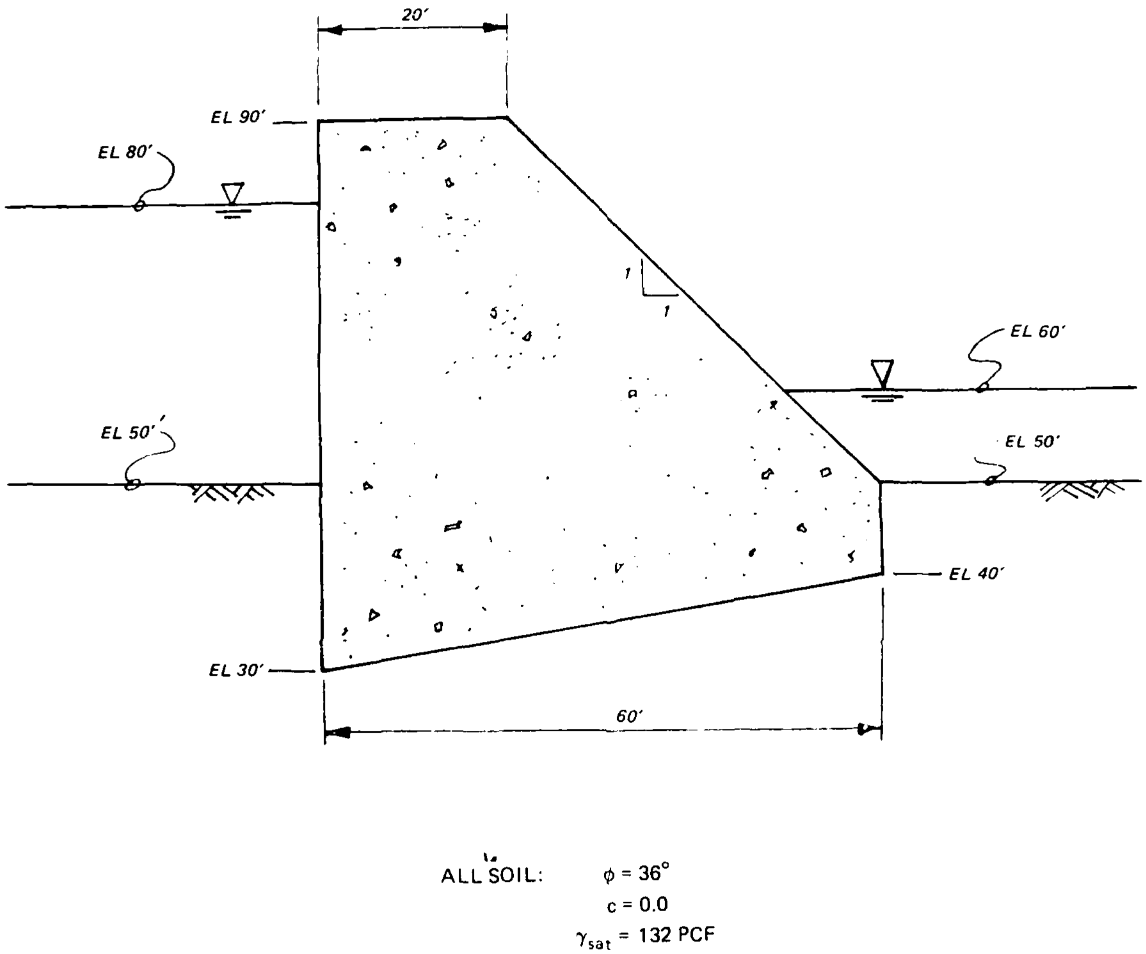
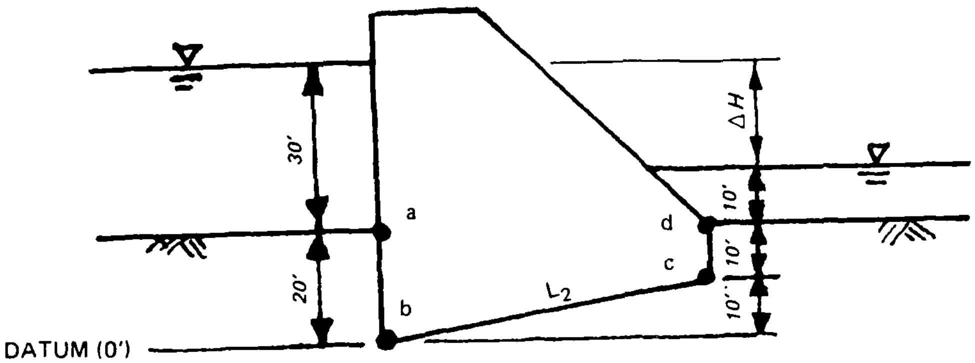


Figure B2. Gravity dam, Problem 2

Water Pressures

24. Water pressures are computed for the different wedges by the line-of-creep method for seepage as follows:



$$\text{Gradient, } i = \frac{\Delta H}{L} = \frac{(50' - 30')}{(20' + 60.828' + 10')} = 0.220197 \text{ ,}$$

where

ΔH = change in total head

L = shortest seepage path; abcd

$$\text{Pressure} = P = \left[\begin{matrix}\text{headwater} \\ \text{elevation}\end{matrix} - \begin{matrix}\text{point} \\ \text{elevation}\end{matrix} - \text{gradient}\begin{pmatrix}\text{path} \\ \text{length}\end{pmatrix}\right]\gamma_{water}$$

$$P_a = (50' - 20')\gamma_w = 1.875 \text{ ksf}$$

$$P_b = [50' - 0' - i(20')]\gamma_w = 2.850 \text{ ksf}$$

$$P_c = [50' - 10' - i(20' + 60.828')]\gamma_w = 1.388 \text{ ksf}$$

$$P_d = [50' - 20' - i(20' + 60.828' + 10')]\gamma_w = 0.625 \text{ ksf}$$

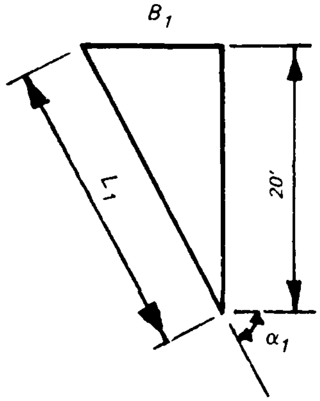
Trial 1

25. For the first iteration in the hand solution of Problem 2, use a safety factor of 1.0 and begin with wedge 1.

Hand Solution, Problem 2

Wedge 1

Dimensions:



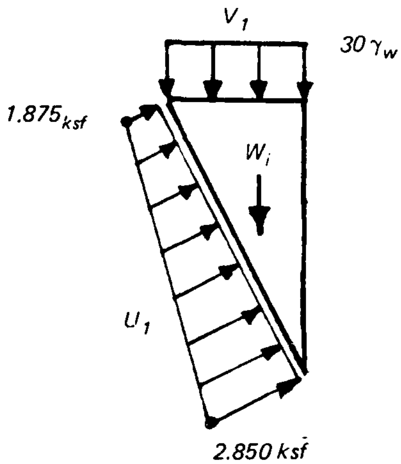
$$\phi_d = \tan^{-1}\left(\frac{\tan \phi_1}{FS}\right) = 36°$$

$$\alpha_1 = -\left(45 + \frac{\phi_d}{2}\right) = -63°$$

$$L_1 = \frac{20'}{\sin \alpha_1} = 22.447'$$

$$B_1 = \frac{20'}{\tan \alpha_1} = 10.191'$$

Forces:



$$V_1 = 30\gamma_w(B) = 19.108^k$$

$$U_1 = \frac{1}{2}(1.875 + 2.850)\ \text{ksf}\ (L_1) = 53.031^k$$

$$W_1 = \frac{1}{2}(20' \times B)(0.132\ \text{kcf}) = 13.452^k$$

$$H_L = 0$$

$$H_R = 0$$

Net force:

$$P_o - P_1 = \frac{\left[(13.452^k + 19.108^k)\cos \alpha_1 - 53.031^k\right]\frac{\tan 36°}{1.0} + (13.452^k + 19.108^k)\sin \alpha_1}{\cos \alpha_1 - \sin \alpha_1\left(\frac{\tan 36°}{1.0}\right)}$$

$$\boxed{P_o - P_1 = -51.574^k}$$

(Continued) (Sheet 1 of 11)

Hand Solution (Continued)

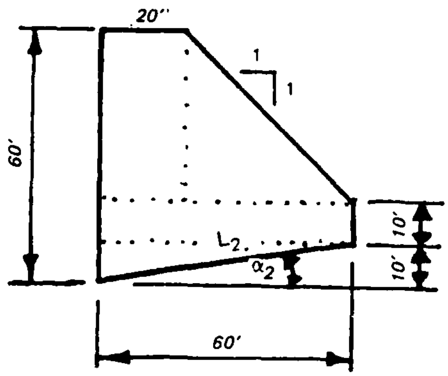
FS = 1.0

Wedge 2

Note: Use a reduced value for ϕ_2 .

$$\phi_2' = \frac{2}{3}\phi_2 = \frac{2}{3}(36°) = 24°$$

Dimensions:



$$\alpha_2 = \tan^{-1}\left(\frac{10'}{60'}\right) = 9.462°$$

$$\sin\alpha_2 = 0.1644$$

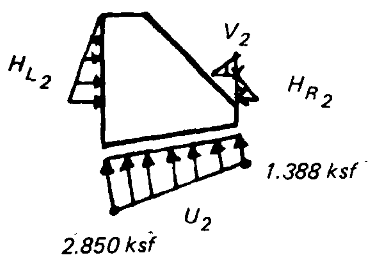
$$\cos\alpha_2 = 0.9864$$

$$L_2 = \sqrt{10^2 + 60^2} = 60.828'$$

$$W_2 = \left[\frac{1}{2}(60 \times 10) + (60 \times 10) + (20 \times 40) + \frac{1}{2}(40 \times 40)\right] 0.150 \text{ kcf}$$

$$= 375.000^k$$

Forces:



$$V_2 = \frac{1}{2}(0 + 10)\gamma_w(10') = 3.125^k$$

$$H_{R_2} = \frac{1}{2}(0 + 10)\gamma_w(10') = 3.125^k$$

$$H_{L_2} = \frac{1}{2}(0 + 30)\gamma_w(30') = 28.125^k$$

$$U_2 = \frac{1}{2}(2.850 + 1.388)\text{ksf } (L_2)$$

$$= 128.895^k$$

(Continued)

(Sheet 2 of 11)

Hand Solution (Continued)

$\boxed{FS = 1.0}$

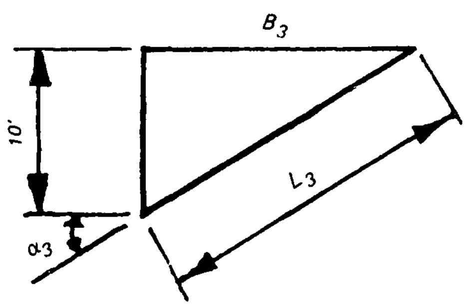
Net force:

$$P_1 - P_2 = \left\{ \frac{[(378.125^k)0.9864 - 128.895^k + (25.000^k)0.1644] \dfrac{\tan 24°}{1.0}}{0.9864 - 0.1644 \dfrac{\tan 24°}{1.0}} \right\}$$

$$+ \left[\frac{-(25.000^k)0.9864 + (378.125^k)0.1644}{0.9864 - 0.1644 \dfrac{\tan 24°}{1.0}} \right]$$

$$\boxed{P_1 - P_2 = 162.076^k}$$

Wedge 3



$$\phi_d = 36°$$

$$\alpha_3 = \left(45 - \frac{\phi_d}{2}\right) = 27°$$

$$\sin \alpha_3 = 0.4540$$

$$\cos \alpha_3 = 0.8910$$

$$L_3 = \frac{10'}{\sin \alpha_3} = 22.026'$$

$$B_3 = \frac{10'}{\tan \alpha_3} = 19.626'$$

$$W_3 = \frac{1}{2}\ (10' \times 19.626')(0.132\ \text{kcf}) = 12.953^k$$

(Continued)

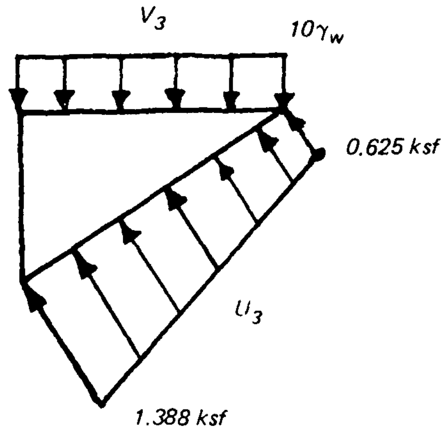
(Sheet 3 of 11)

Hand Solution (Continued)

$\boxed{FS = 1.0}$

Wedge 3

Forces:



$$V_3 = 10\gamma_w(B_3) = 12.266'$$

$$U_3 = \frac{1}{2}(1.388 + 0.625)\text{ ksf }(22.026')$$

$$= 22.169^k$$

$$H_{L_3} = H_{R_3} = 0$$

Net force:

$$P_2 - P_3 = \frac{[(25.219^k)0.8910 - 22.169]\,\frac{\tan 36°}{1.0} + (25.219^k)0.4540}{0.8910 - 0.4540\,\frac{\tan 36°}{1.0}}$$

$$\boxed{P_2 - P_3 = 20.793^k}$$

a. The sum of net forces for Trial 1, FS = 1.0 , is as follows:

$$\sum(P_{i-1} - P_i) = -51.574^k + 162.076^k + 20.793^k = 131.295^k$$

b. This large sum indicates the actual safety factor is much greater than 1.0.

(Continued)

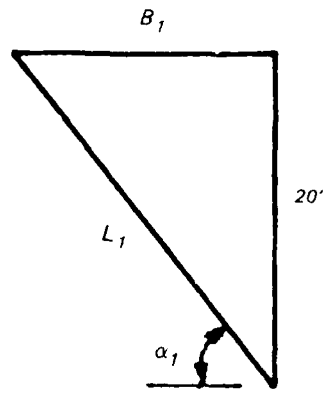
(Sheet 4 of 11)

Trial 2

26. For the second iteration, use a trial FS equal to 10.0.

$\boxed{FS = 10.0}$

Wedge 1



$$\phi_d = \tan^{-1}\left(\frac{\tan 36°}{10.0}\right) = 4.155°$$

$$\alpha_1 = -\left(45 + \frac{4.155}{2}\right) = -47.078°$$

$$\sin \alpha_1 = -0.7323$$

$$\cos \alpha_1 = 0.6810$$

$$L_1 = \frac{20}{\sin \alpha_1} = 27.312'$$

$$B_1 = \frac{20}{\tan \alpha_1} = 18.600'$$

$$W_3 = \frac{1}{2}\,(20 \times 18.600')(0.132 \text{ kcf}) = 24.552^k$$

$$V_1 = 30\gamma_w(18.600') = 34.875^k$$

$$U_1 = \frac{1}{2}\,(1.875 + 2.850)\text{ksf }(27.312') = 64.525^k$$

$$H_{L_1} = H_{R_1} = 0$$

Net force:

$$P_o - P_1 = \frac{[(59.427^k)0.6810 - 64.525^k]\,\dfrac{\tan 36°}{10.0} + (59.427^k)(-0.7323)}{0.6810 - (-0.7323)\left(\dfrac{\tan 36°}{10.0}\right)}$$

$$\boxed{P_o - P_1 = -61.653^k}$$

(Continued)

(Sheet 5 of 11)

Hand Solution (Continued)

$\boxed{FS = 10.0}$

Wedge 2

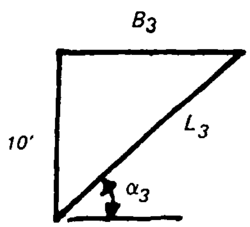
a. All the forces and dimensions of this wedge remain the same throughout the iterations. Therefore, the only change in the net force is from the change in the safety factor.

$$P_1 - P_2 = \frac{(248.198^k)\ \dfrac{\tan 24°}{10.0} + 37.504^k}{0.9864 - 0.1644\left(\dfrac{\tan 24°}{10.0}\right)}$$

$$\boxed{P_1 - P_2 = 49.592^k}$$

Wedge 3

$$\alpha_3 = \left(45 - \frac{4.155}{2}\right) = 42.922°$$



$$\sin \alpha_3 = 0.6810$$

$$\cos \alpha_3 = 0.7323$$

$$L_3 = \frac{10}{\sin \alpha_3} = 14.684'$$

$$B_3 = \frac{10}{\tan \alpha_3} = 10.753'$$

$$W_3 = \frac{1}{2}\ (10' \times 10.753')(0.132\ \text{kcf}) = 7.097^k$$

$$U_3 = \frac{1}{2}\ (1.388 + 0.625)\text{ksf}\ (14.684') = 14.779^k$$

$$V_3 = 10\gamma_w(10.753') = 6.721^k$$

$$H_{L_3} = H_{R_3} = 0$$

(Continued)

(Sheet 6 of 11)

$\boxed{FS = 10.0}$

Wedge 3

Net force:

$$P_2 - P_3 = \frac{\left[(13.818)0.7323 - 14.779^k\right] \dfrac{\tan 36°}{10.0} + (13.818^k)0.6810}{0.7323 - 0.6810 \dfrac{\tan 36°}{10.0}}$$

$$\boxed{P_2 - P_3 = 13.285^k}$$

b. The sum of net forces for Trial 2, FS = 10.0 , is as follows:

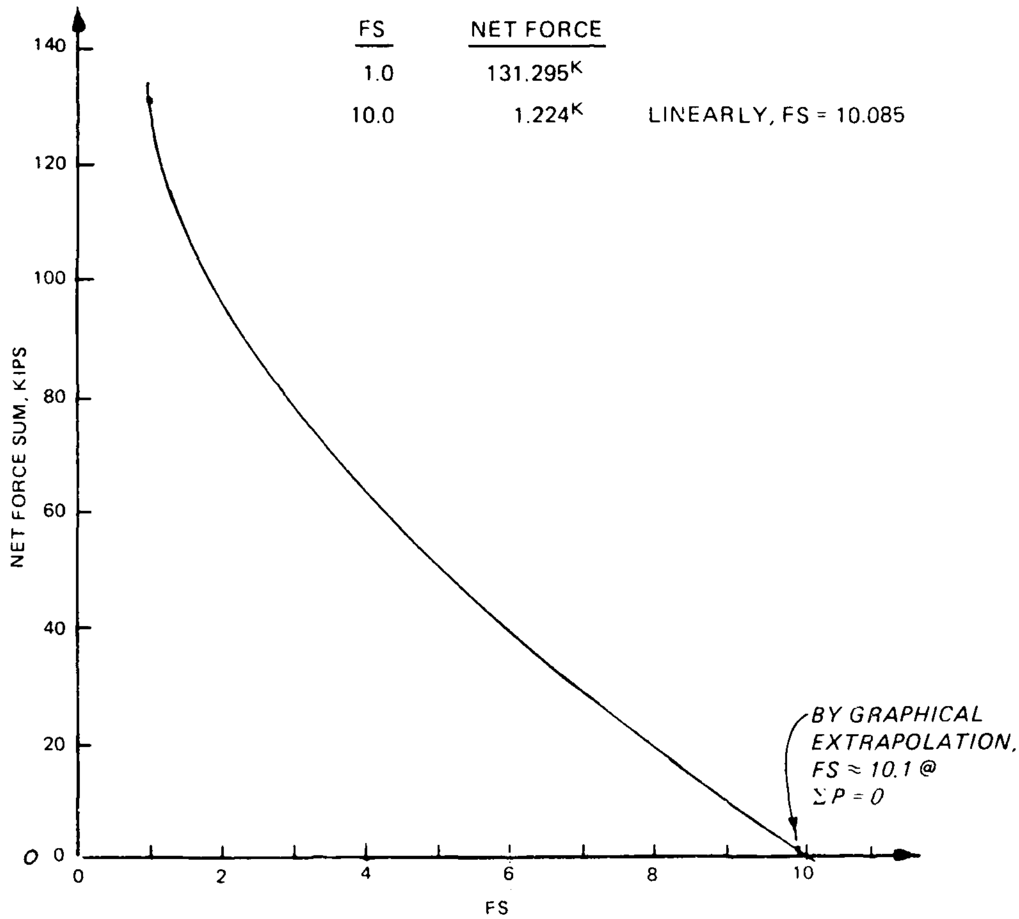
$$\sum (P_{i-1} - P_i) = -61.653 + 49.592 + 13.285 = 1.224^k$$

The result indicates the actual safety factor is slightly greater than 10.0.

27. The results of graphical and linear extrapolation for the next safety factor to be used are shown on the following page.

(Continued)

Hand Solution (Continued)



(Continued)

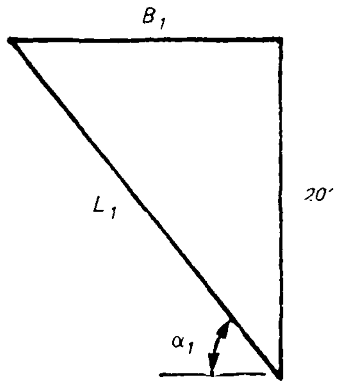
(Sheet 8 of 11)

Trial 3

28. For the third iteration, use a trial FS equal to 10.1.

$\boxed{FS = 10.1}$

Wedge 1



$$\phi_d = \tan^{-1}\left(\frac{\tan 36°}{10.1}\right) = 4.114°$$

$$\alpha_1 = -\left(45° + \frac{4.114°}{2}\right) = -47.057°$$

$$\sin \alpha_1 = -0.7320$$

$$\cos \alpha_1 = 0.6813$$

$$L_1 = \frac{20}{\sin \alpha_1} = 27.322'$$

$$B_1 = \frac{20}{\tan \alpha_1} = 18.613'$$

$$W_1 = \frac{1}{2}(20' \times 18.613')(0.132 \text{ kcf}) = 24.569^k$$

$$V_1 = 30\gamma_w(18.613') = 34.899^k$$

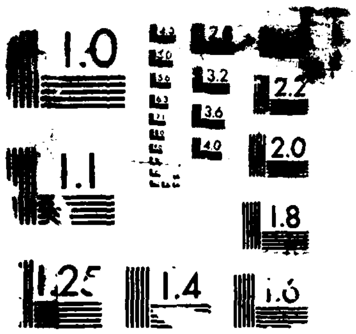
$$U_1 = \frac{1}{2}(1.875 + 2.850)\text{ksf } (27.322') = 64.548^k$$

Net force:

$$P_o - P_1 = \frac{[(59.469^k)0.6813 - 64.548^k (\frac{\tan [illegible]}{10.1} [illegible]}{0.6813 - [illegible] ([illegible]}$$

$$\boxed{P_o - P_1 = -61.666^k}$$

AD-A189 334 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT 4/4
SLIDING STABILITY OF..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS INFOR..
UNCLASSIFIED M E PACE ET AL. OCT 87 WES/TR/ITL-87-5 F/G 12/5 NL



MICROCOPY RESOLUTION TEST CHART

Hand Solution (Continued)

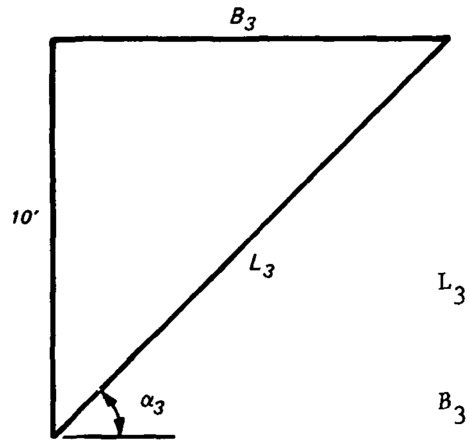
$\boxed{FS = 10.1}$

Wedge 2

$$P_1 - P_2 = \frac{(248.198^k)\ \dfrac{\tan 24°}{10.1} + 37.504^k}{0.9864 - 0.1644\left(\dfrac{\tan 24°}{10.1}\right)}$$

$$P_1 - P_2 = 49.477^k$$

Wedge 3



$$\alpha_3 = \left(45 - \frac{4.114}{2}\right) = 42.943°$$

$$\sin \alpha_3 = 0.6813$$

$$\cos \alpha_3 = 0.7320$$

$$L_3 = \frac{10}{\sin \alpha_3} = 14.678'$$

$$B_3 = \frac{10}{\tan \alpha_3} = 10.745'$$

$$W_3 = \frac{1}{2}\ (10' \times 10.745')(0.132 \text{ kcf}) = 7.092^k$$

$$U_3 = \frac{1}{2}\ (1.388 + 0.625)\text{ksf}\ (14.678') = 14.773^k$$

$$V_3 = 10\gamma_w(10.745') = 6.716^k$$

Net force:

$$P_2 - P_3 = \frac{[(13.808^k)0.7320 - 14.773^k]\ \dfrac{\tan 36°}{10.1} + (13.808)0.6813}{0.7320 - 0.6813\left(\dfrac{\tan 36°}{10.1}\right)}$$

$$\boxed{P_2 - P_3 = 13.282^k}$$

(Continued)

(Sheet 10 of 11)

Hand Solution (Concluded)

a. The sum of net forces for Trial 3, FS = 10.1 ,is as follows:

$$\sum (P_{i-1} - P_i) = -61.666 + 49.477 + 13.282 = 1.093^k$$

b. The positive sum of forces indicates that the actual safety factor is still slightly greater than 10.1. However, relative to the magnitude of the safety factor, this sum of forces is close to zero and the iterations are stopped at this point. The safety factor is a conservative 10.0.

c. CSLIDE is now used to analyze the problem and find the actual safety factor for sliding.

(Sheet 11 of 11)

29. The data file for the CSLIDE analysis is shown below, followed by the echoprint of this input data.

```
00100 TITL CHECK HAND SOLUTION FOR DAM #2
00110 STRU 5 .15
00120 40 30 40 90 60 90 100 50 100 40
00130 SOLT 1 1 36 0 .132 50
00140 -300 50
00150 SORT 1 1 36 0 .132 50
00160 300 50
00170 SOST 24 0
00180 METH 1
00190 WATR 80 60 .0625
00200 END
```

```
--------------------------------
  PROGRAM CSLIDE - ECHOPRINT
--------------------------------

DATE:  86/06/19.                          TIME:  13.38.49.

CHECK HAND SOLUTION FOR DAM #2

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE BY LINE OF CREEP, GRADIENT
COMPUTED USING SHORTEST SEEPAGE PATH .

NO OF CORNERS IN STRUCTURE ----------       5
DENSITY OF CONCRETE -----------------   .1500(KCF)
DENSITY OF WATER --------------------   .0625(KCF)
WATER LEVEL LEFT SIDE ---------------   80.00(FT)
WATER LEVEL RIGHT SIDE --------------   60.00(FT)
NO. OF SOIL LAYERS LEFT SIDE --------       1
NO. OF SOIL LAYERS RIGHT SIDE -------       1


STRUCTURE INFORMATION
---------------------
POINT         X-COORD        Y-COORD
-----         -------        -------


   1           40.00          30.00
   2           40.00          90.00
   3           60.00          90.00
   4          100.00          50.00
   5          100.00          40.00

 LEFTSIDE SOIL DATA
 ------------------

          FRICTION                     UNIT          ELEV AT
  LAYER    ANGLE        COHESION       WEIGHT        STRUCTURE
   NO.     (DEG)         (KSF)         (KCF)           (FT)
 ---------------------------------------------------------


   1       36.00         .0000          .132          50.00
```

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	-300.00	50.00

SOIL DATA BELOW STRUCTURE

FRICTION ANGLE --------- 24.00
COHESION --------------- .0000

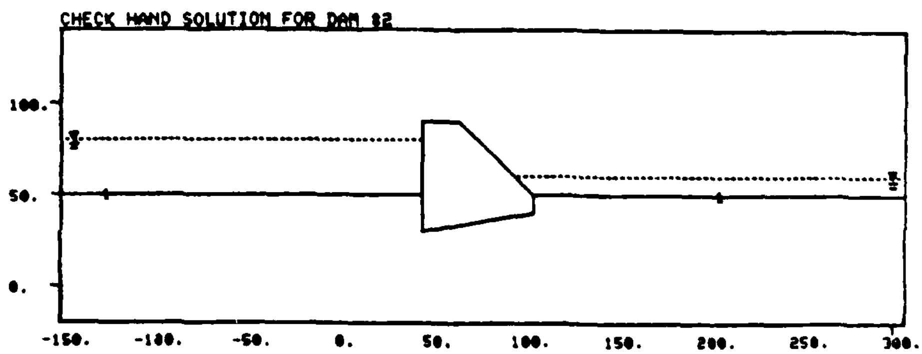
RIGHTSIDE SOIL DATA

LAYER NO.	FRICTION ANGLE (DEG)	COHESION (KSF)	UNIT WEIGHT (KCF)	ELEV AT STRUCTURE (FT)
1	36.00	.0000	.132	50.00

LAYER NO	POINT NO. 1 X-COORD	Y-COORD
1	300.00	50.00

DO YOU WANT TO PLOT THE INPUT DATA. ENTER 'Y' OR 'N'.
? Y

30. The plot of input data is shown, followed by final results of this analysis.



Plot of input data, Problem 2

PROGRAM CSLIDE - FINAL RESULTS

DATE: 86/06/19.　　　　TIME: 13.40.19.

CHECK HAND SOLUTION FOR DAM #2

SINGLE FAILURE PLANE ANALYSIS

SEEPAGE FORCE COMPUTED BY LINE OF CREEP

WEDGE NUMBER	HORIZONTAL LOADS LEFT SIDE (KIPS)	HORIZONTAL LOADS RIGHT SIDE (KIPS)	VERTICAL LOAD (KIPS)
1	.000	.000	35.093
2	28.125	3.125	3.125
3	.000	.000	6.679

WATER PRESSURES ON WEDGES

LEFTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
1	1.875	2.850

STRUCTURAL WEDGE

X-COORD. (FT)	PRESSURE (KSF)
40.00	2.850
100.00	1.388

RIGHTSIDE WEDGES

WEDGE NO.	TOP PRESSURE (KSF)	BOTTOM PRESSURE (KSF)
3	.625	1.388

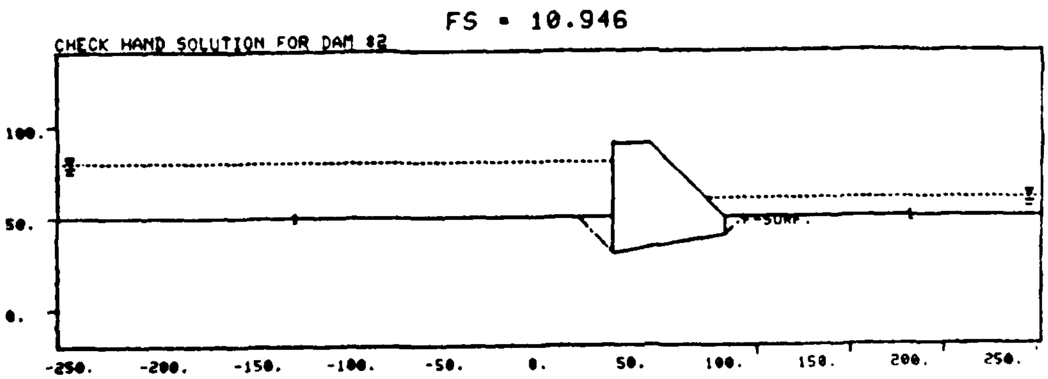
WEDGE NUMBER	FAILURE ANGLE (DEG)	TOTAL LENGTH (FT)	WEIGHT OF WEDGE (KIPS)	SUBMERGED LENGTH (FT)	UPLIFT FORCE (KIPS)
1	-46.899	27.392	24.705	27.392	64.709
2	9.462	60.828	375.000	60.828	128.875
3	43.101	14.635	7.053	14.635	14.728

WEDGE NUMBER	NET FORCE ON WEDGE (KIPS)
1	-61.831
2	48.586
3	13.245

SUM OF FORCES ON SYSTEM ---- .000

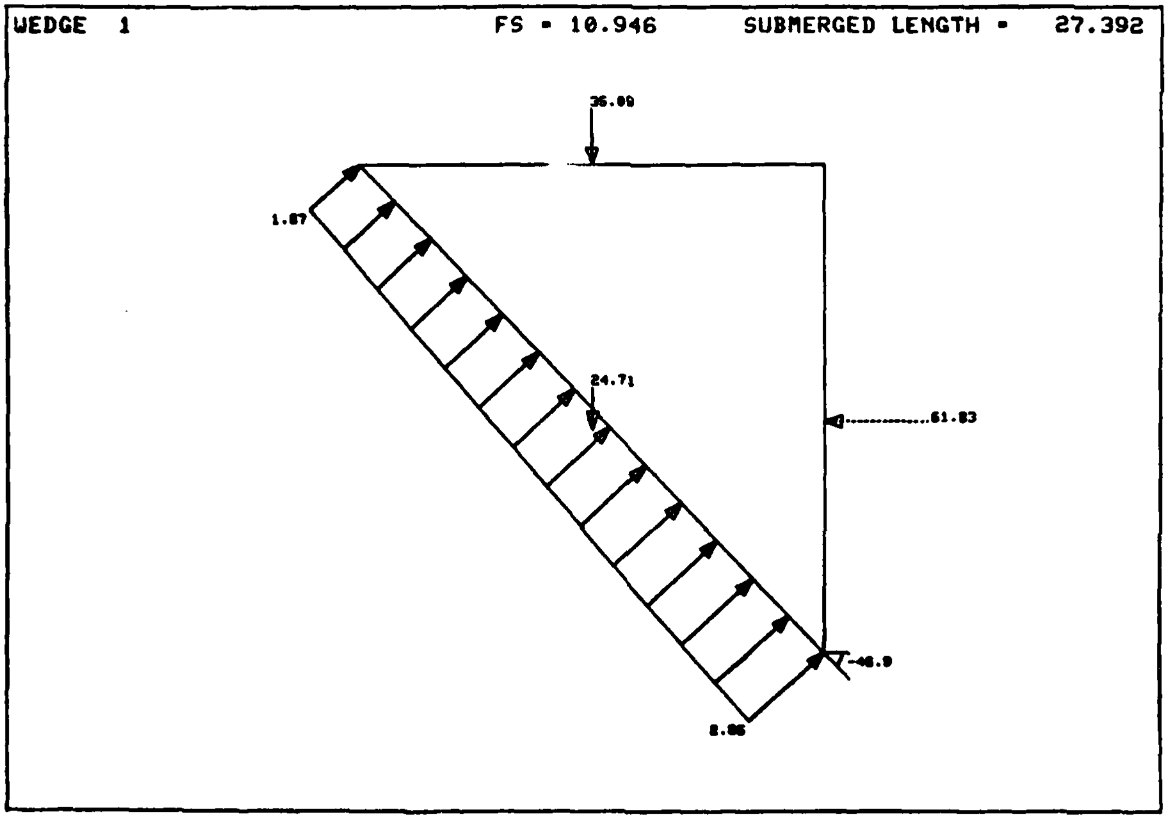
FACTOR OF SAFETY ----------- 10.946

31. The plot of the failure surface is shown, followed by the plots of the three wedges.

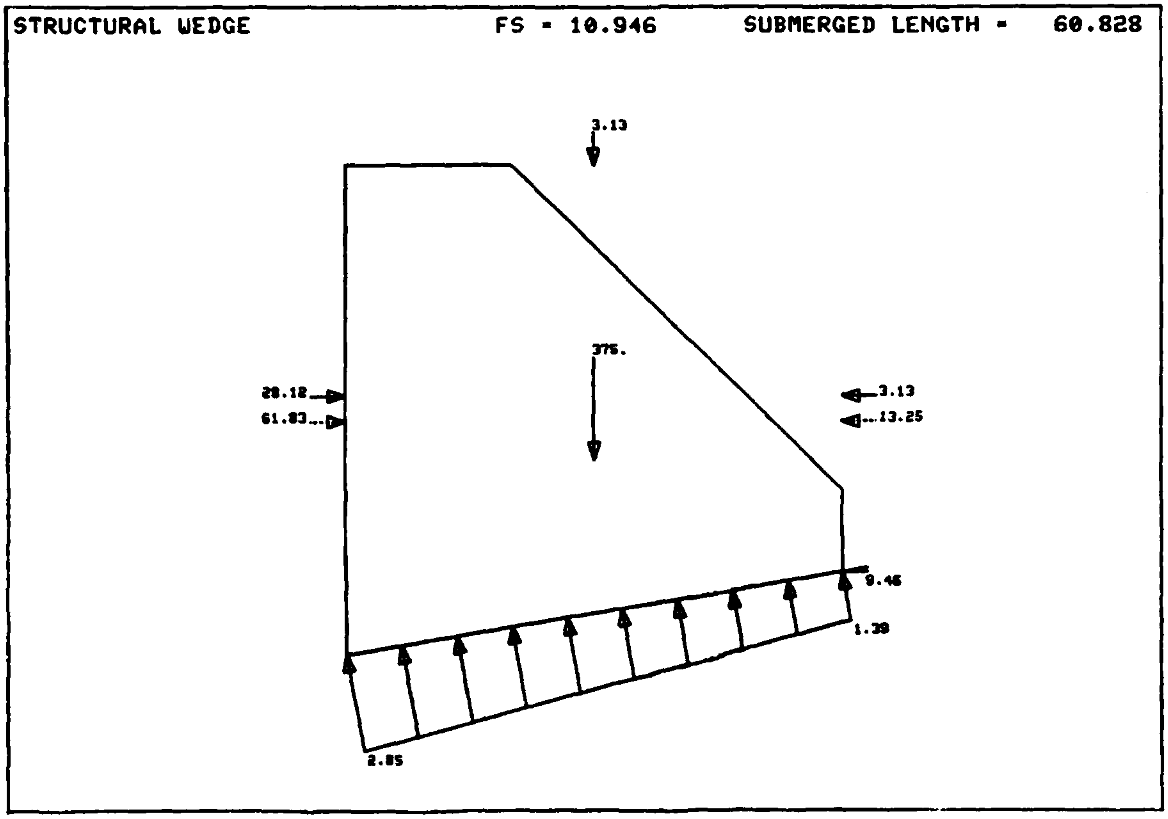


Plot of failure surface, Problem 2

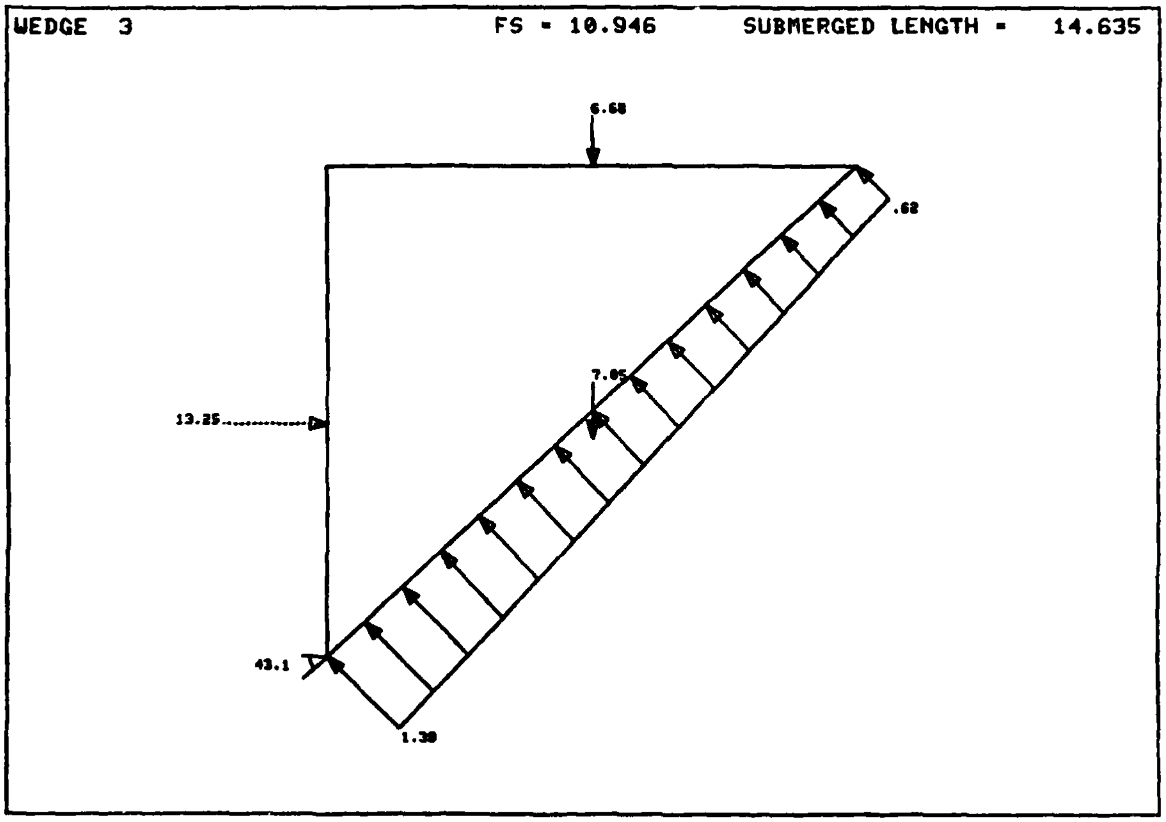
CHECK HAND SOLUTION FOR DAM #2



CHECK HAND SOLUTION FOR DAM #2



CHECK HAND SOLUTION FOR DAM #2

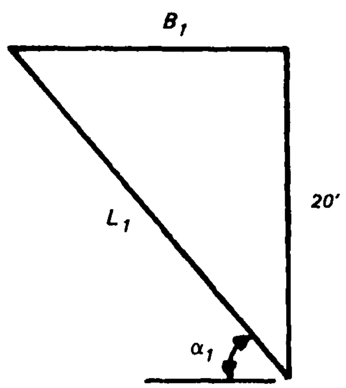


Hand Check of CSLIDE Final Results

32. The safety factor obtained from the CSLIDE analysis is used to compute forces and wedges in a final hand iteration.

$\boxed{FS = 10.946}$

Wedge 1



$$\phi_d = \tan^{-1}\left(\frac{\tan 36°}{10.946}\right) = 3.797°$$

$$\alpha_1 = -\left(45 + \frac{\phi_d}{2}\right) = -46.899°$$

$$\sin \alpha_1 = -0.7301$$

$$\cos \alpha_1 = 0.6833$$

$$L_1 = \frac{20}{\sin \alpha_1} = 27.394'$$

$$B_i = \frac{20}{\tan \alpha_1} = 18.716'$$

$$W_1 = \frac{1}{2}\ (20' \times 18.716')(0.132\ \text{kcf}) = 24.706^k$$

$$V_1 = 30\gamma_w(18.716') = 35.093^k$$

$$U_1 = \frac{1}{2}\ (1.875 + 2.850)\text{ksf}\ (27.394') = 64.718^k$$

$$H_{L_1} = H_{R_1} = 0$$

(Continued)

$\boxed{FS = 10.946}$

Net force:

$$P_o - P_1 = \frac{[(59.799^k)0.6833 - 64.718^k] \frac{\tan 36°}{10.946} + (59.799)(-0.7301)}{0.6833 - (-0.7301) \frac{\tan 36°}{10.946}}$$

$$P_o - P_1 = -61.827^k$$

Wedge 2

$$P_1 - P_2 = \frac{(248.198^k) \frac{\tan 24°}{10.946} + 37.504}{0.9864 - 0.1644\left(\frac{\tan 24°}{10.946}\right)}$$

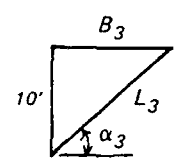
$$\boxed{P_1 - P_2 = 48.585^k}$$

Wedge 3

$$\alpha_3 = \left(45 - \frac{\phi_d}{2}\right) = 43.101°$$

$$\sin \alpha_3 = 0.6833$$

$$\cos \alpha_3 = 0.7301$$



$$W_3 = \frac{1}{2} (10' \times 10.686')0.132 \text{ kcf} = 7.053^k$$

$$L_3 = \frac{10}{\sin \alpha_3} = 14.635'$$

$$V_3 = 10\gamma_w(10.686') = 6.679^k$$

$$U_3 = \frac{1}{2} (1.388 + 0.625)\text{ksf } (14.635') = 14.730^k$$

$$B_3 = \frac{10}{\tan \alpha_3} = 10.686'$$

(Continued)

Hand Check (Concluded)

Net forces:

$$P_2 - P_3 = \frac{[(13.732^k)0.7301 - 14.730]\,\frac{\tan 36°}{10.946} + (13.732)0.6833}{0.7301 - 0.6833\left(\frac{\tan 36°}{10.946}\right)}$$

$$\boxed{P_2 - P_3 = 13.247^k}$$

33. The sum of net forces for FS = 10.946 is:

$$\sum (P_{i-1} - P_i) = -61.827 + 48.585 + 13.247 = 0.005^k$$

(Sheet 3 of 3)

Results Summary

34. The CSLIDE and hand-checked results are compared in the following tabulation.

Water Pressures--same for both sets of results

	Top	Bottom
Wedge 1	1.875 ksf	2.850 ksf
2	2.850 ksf	1.388 ksf
3	0.625 ksf	1.388 ksf

Forces:

Wedge	Net Horizontal (kips)		Vertical (kips)		Uplift (kips)	
No.	CSLIDE	Hand	CSLIDE	Hand	CSLIDE	Hand
1	0.000	0.0	35.093	35.093	64.709	64.718
2	25.000	25.0	3.125	3.125	128.875	128.895
3	0.000	0.0	6.679	6.679	14.728	14.730

Geometry and net force:

Wedge	Failure Angle (deg)		Weight (kips)		Net Force (kips)	
No.	CSLIDE	Hand	CSLIDE	Hand	CSLIDE	Hand
1	-46.899	-46.899	24.705	24.706	-61.831	-61.827
2	9.462	9.462	375.000	375.000	48.586	48.585
3	43.101	43.101	7.053	7.053	13.245	13.247
			Sum of net forces		0.000	0.005

APPENDIX C: DISCUSSION OF PROGRAM CSLIDE

1. The computer program, CSLIDE, which implements the procedures discussed earlier in this report, is written in Fortran 77. The program provides interactive operation from a remote terminal. All arithmetic operations are performed in single precision. A discussion of each routine in CSLIDE is provided below along with a basic flow chart of the program.

Main

2. The Main routine controls the following items:

a. The method of data entry, either from the terminal or a file.

b. The destination of the output to either the terminal, a file, or both.

c. The type of output desired, either final results or all iterations.

d. The solution process as shown in the flowchart in Figure C1.

Subroutines

3. The program contains 38 subroutines. The basic function of each subroutine is discussed in the following list:

CCRETE	-	reads in the coordinates of the points defining the structure and calculates the weight of the structure
CONTROL	-	reads data from the terminal or a file using a keyword format
DALCR	-	computes the critical failure angles of the right-side wedges for a multiple-plane failure analysis
DALPHA	-	sets the initial failure angles of the right-side wedges to $45 + \phi/2$
DCRIT	-	computes the critical failure angles of the right-side wedges for a single-plane failure analysis
DNSTRM	-	reads in the coordinates and soil properties of the right-side soil layers
DSCRIP	-	prints a condensed version of the user's guide at the terminal
DWEDGE	-	calculates the weight and uplift force for the right-side wedges for a given failure angle
ECHO	-	prints the input data to the terminal and/or a file
EDIT	-	allows the user to edit selected sections of the current data and rerun the problem

EXTRA - calculates the weight of any soil below the base of the structure that is included in the structural wedge

FEXT - reads in any external forces which act on the system

FILEIN - attaches the input data file

FINDX - calculates the coordinates of the points where the soil layers intersect the structure

FNDLD - calculates the total applied external forces, both horizontal and vertical, which act on a particular wedge

GETPFN - accesses a permanent file from the user's catalog

HEADER - reads in a title for a problem

LEFT - finds the intersection point of a failure angle with a soil surface for the left-side wedges

NEW - initializes variables for use when more than one problem is analyzed

PLOT - plots the input data and the output results

PRESS - calculates the sum of the net forces acting on the wedges

PRINT - prints the results of an analysis

RIGHT - finds the intersection of a failure angle and a soil layer for the right-side wedges

SAVEIN - saves the input data to a permanent file

SET - allows the user to specify the failure angle of any wedge.

SOLVE - finds the intersection of two lines

SORT - sorts in order and stores each distinct x-coordinate of all the soil layers for a particular side and calculates the y-coordinate of each layer at each distinct x-coordinate

STRIP - removes the line numbers from an input data file

SWEDGE - calculates the weight of the structural wedge and the uplift force acting on it

TYPE - reads in the method of analysis, safety factor ratio, and the upper and lower bounds for the FS

VALCR - calculates the critical failure angles of the left-side wedges for the multiple-plane failure analysis

VALPHA - sets the initial failure angles of the left-side wedges to $(45 - \phi/2)$

VCRIT - calculates the critical failure angles for the left-side wedge for the single-plane failure analysis

VNDER - reads in the properties of the soil below the structure

VPSTRM - reads in the coordinates and soil properties of the left-side soil layers

VWEDGE - calculates the weight and uplift force for the left-side wedges of a particular failure angle

WATR - reads in the elevation of the water on the left and right sides of the structure, the desired method to compute uplift pressures, an uplift force on the structural wedge, and water pressures on the wedges

Functions

4. The program contains 11 functions. The purpose of each function is discussed in the following list:

ANGL - calculates $\phi/2$

BOX - defined as:

$\mathrm{Box}(x) = x$, if $x \geq 0$

$\mathrm{Box}(x) = 0$, if $x < 0$

DEL - calculates the elevation of a soil layer on the right side at a specified x-coordinate

DR - converts degrees to radians

PCOMP - calculates the net force $P_{i-1} - P_i$ on a given wedge using the general wedge equation

RD - converts radians to degrees

SEEP2 - calculates the water pressures at the vertices of each wedge using the line-of-creep method and calculates an uplift force on each wedge

SEEP3 - calculates the uplift force on a certain wedge using water pressures entered by the user

VEL - calculates the elevation of a specified x-coordinate for a soil layer on the left side

XINTER - interpolates between two sets of coordinates

WLAY - calculates the weight of a soil layer in a given wedge

Flowchart

5. A basic flowchart of the program CSLIDE is shown in Figure C1.

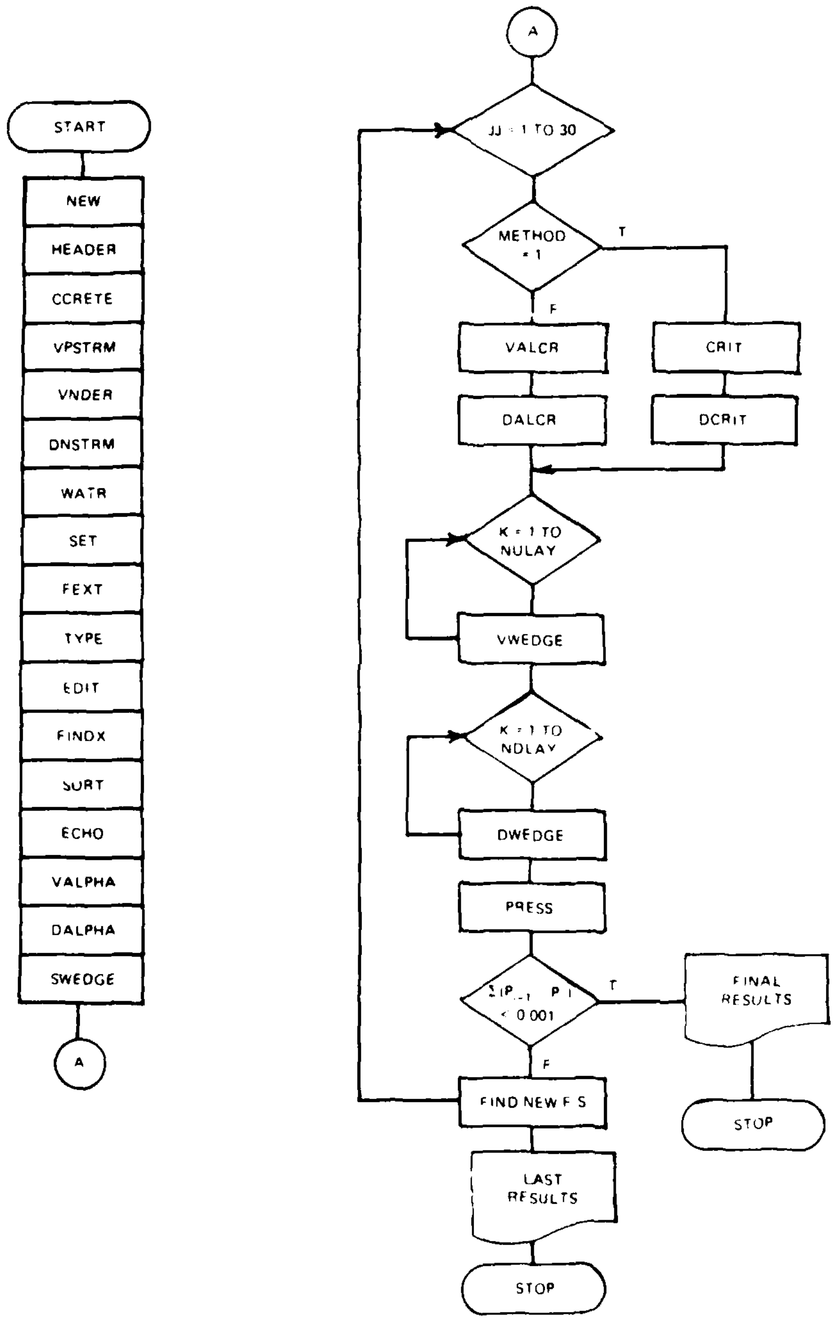


Figure C1. Flowchart of CSLIDE

APPENDIX D: NOTATION

c	Cohesion
F	Forces
FS	Factor of safety against sliding
h	Total head measured from an arbitrary datum
h_L	Head loss between two arbitrary points
h_{L_P}	Head loss incurred going to point P
H	Total head loss of system
H_L	Any horizontal force applied on the left side of a wedge which is above the top or below the bottom of an adjacent wedge
H_R	Any horizontal force applied on the right side of a wedge which is above the top or below the bottom of an adjacent wedge
$i, i-1, i+1$	Body or surface forces, dimensions or properties associated with the i^{th} wedge
L	Length of the base of a wedge along the failure surface
n	Axes normal to failure plane
N	Resultant normal force acting on the base of a wedge
P	Resultant earth force and water force acting on the vertical boundaries of a typical wedge
P_P	Water pressure at an arbitrary point P
P_w	Pressure at an arbitrary point
t	Axes tangent to failure plane
T	Shearing force acting along the base of a wedge
T_F	Maximum shearing force along the base of a wedge which is available to resist sliding
U	Uplift force due to water forces acting on the base of a wedge
V	Any vertical force applied to a wedge, from above the top of the wedge
W	Total weight of concrete, water, and soil contained in a wedge
z	Elevation head of an arbitrary point
z_P	Elevation head of point P
α	Angle between the inclined plane of the base of a wedge and the horizontal
γ	Weight per unit volume
δ	Angle of wall friction between concrete and soil
σ	Normal stress
τ	Applied shear stress
τ_F	Maximum shear strength at failure
ϕ	The angle of shearing resistance or angle of internal friction

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (SHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

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WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report K-83-1	User's Guide: Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide: A Three Dimensional Stability Analysis/Design Program (3DSAD), Report 1, Revision 1: General Geometry Module	Jun 1987
Instruction Report ITL-87-4	User's Guide: 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies—Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies—Closed Sections	Aug 1987

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WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

	Title	Date
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate [illegible]	[illegible]
	Report 5: Alternate Configuration Miter Gate Finite Element Studies—Additional Closed Sections	
	Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates	
	Report 7: Application and Summary	
	Report 8: User's Guide for Design [illegible] Horizontally Framed Miter Gates (CMITER)	
	Report 9: Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume [illegible] User's Manual	[illegible] 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987

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